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SCHOOL SCIENCE AND MATHEMATICS

VOL. XXIII, No. 5 MAY, 1923 WHOLE No. 196

THE PRESENT CONTENT OF BIOLOGY IN THE SECONDARY SCHOOLS.

BY OSCAR W. RICHARDS,

University of Oregon, Eugene.

The biology courses in the secondary schools are not standardized in the sense of covering a similar course in many schools in different parts of the country, as one finds in the older subjects like the three R's. This condition was noted in a study of the courses in the high schools in those cities in the United States which have a population of one hundred thousand or over. In a previous paper[1] it was shown that the fifty nine cities studied used sixty-seven different text and reference books. This paper further indicated that in order to determine accurately what was the representative course in biology it would be necessary to know the training and experience of each individual teacher as well as the course that he or she actually taught. The composite course could then be built from this data. This would be an all but impossible task which time would not permit. Consequently the first six books on the list have been chosen as being representative of the courses in general and they will be analyzed in detail in this paper. The data received indicates that these six books do represent the courses as reported in about seventy-five per cent of the replies received. Also they will be still more indicative of the average course in biology when we recall that in many of the smaller schools the teachers tend to follow a text more closely, for, in many cases, they have not had the necesary training to plan a course for their locality or they do not have the time and facilities necessary to formulate and use a course of their own devising.

Since these books were sufficiently representative of the different courses for the need in hand, namely the preparation of a

[1]Richards, O. W. The present status of biology in the secondary schools. School Review XXXI, 2. February, 1923.

pedagogical test to measure achievement in biology, it is necessary to formulate some criterion for the evaluation of the different topics and books. The average number of words used was chosen for this criterion because it is the simplest and perhaps the most accurate index of the relative importance of the different topics. The average number of words on each page was estimated by finding the average number of words to a line from at least ten different pages and multiplying this by the number of lines. Then the number of words to the chapter was estimated by counting the average number of complete pages, leaving out the space occupied by illustrations, and multiplying by the above average. Laboratory suggestions, classification outlines and similar data were estimated separately. They are reported in this paper under the heading of outline as contrasted with the words of the text.

In addition to the number of words the number of illustrations were counted in three groups. In the first group (A) were included pictures of men, historical documents or illustrations having to do with the history of the biology. Class B were pictures such as half tones or a pictorial nature. The third class C comprised sketches, sections, charts and schematic dissections.

These data were placed on slips of paper, two and one-half by one inch in size, along with the book number, chapter heading and a very brief sketch of the contents of that chapter. One such slip was made out for each chapter of each book. Then each slip for each book was tabulated for the data of table I. The slips for Hunter's "Essentials of Biology" were then pinned to a long strip of cloth in their normal sequence. These slips were chosen because they were the most representative of the topics of the different books. Then the slips of the other books were placed in vertical columns under the headings of the slips of the first book. If there was no suitable heading for a given slip another column was made for it. This gave an approximation of the amount written under each of the thirty-five topics. Such a classification is not entirely satisfactory as the number of topics is rather small. Also the smallest unit must be the chapter. This made about the minimum number of topics that could be handled with a fair amount of accuracy. Dividing the chapters would necessitate more work than the slight increase of detail would seem to justify.

The general data in regard to the length of the books, the date published and number of illustrations is recorded in Table I.

Since the lengths of the books are about the same, the time of publication apparently had no effect on the amount of material, as judged by the number of words written. Perhaps the most interesting item is that the most recently published book, Gruenberg's "Biology" has three times the number of chapter headings of any of the others and has fewer illustrations than three of the other six.

TABLE I. GENERAL ANALYSIS OF BOOKS.

Book No.	Name	Date Pub.	No. Ch.	Words Page	No. Pages	Illus. A.	Illus. B.	Illus. C.	Illus. Tot'l	No. of Words Text	No. of Words Out-line	No. of Words Total
1	Bergen and Caldwell Practical Botany......	1911	26	360	545	....	211	176	387	119080	1845	120925
2 2	Hunter, Civic Biology............	1914	25	407	432	4	154	169	327	108109	7264	115373
3	Hunter, Essentials of Biology	1911	29	418	448	1	231	146	378	128177	1950	130127
4	Linnville and Kelley General Zoology........	1906	32	340	426	4	112	100	216	107485	397	107882
5	Gruenberg, Biology......................	1919	91	350	528	....	39	218	257	118448	6332	124780
6	Peabody and Hunt Elementary Biology	1913	27	333	229	8	68	202	278	94496	34950	129446

The thirty-five topics are listed in table II in the order of the amount that has been written on them. This order represents about the order and the importance that is given to the different subjects in the average high school course in the United States. Some of the topics are given relatively more importance because two of the books (e. g. Linnville and Kelley's "General Zoology," and Peabody and Hunt's "Botany") treat some few of the topics to the exclusion of others. The first topic takes first place in that it includes more material than any of the other topics. The table as a whole gives the average situation. In order that the effect of each book on the average could be easily understood Table III gives the same data as does Table II but lists it according to each of the six different books.

TABLE II. THE AVERGAE BIOLOGY COURSE.

No.	Topic	No. Ch.	No. of Words		
			Totl	Text	Outline
1	Vertebrate animals. Fish, birds, mammals, frogs, etc.	14	68009	62320	5689
2	Insects, various orders	16	51864	48409	3455
3	Forms of lower plants, algae, fungi, ferns, mosses	10	51282	50119	1163
4	Improvement of environment. Breeding public health	17	47155	45148	2007
5	Foods and dietetics, alcohol and drugs	14	39873	34933	4940
6	Health and disease	6	30155	27676	2479
7	Seeds and seedlings	7	26566	22662	3904
8	Respiration and excretion	10	25644	25018	626
9	Classification	9	24031	22106	1925
10	Nervous system and sense organs	9	22943	22284	659
11	Structure and work of stem	7	22633	20930	1703
12	Metazoa in general. Division of labor	5	21284	20966	318
13	Molluscs	7	21267	20089	1178
14	Plants in relation to human welfare	3	20839	20412	427
15	Flowers and their work	7	20801	17200	3601
16	Blood and circulation	8	20512	19814	698
17	Digestion and absorption	4	19589	17085	2504
18	Surroundings or environment	9	18977	17376	1601
19	Roots and their work	7	17844	15576	2268
20	Functions and structures of living things	8	15609	14852	757
21	Interrelations of plants and animals	4	14885	14514	371
22	Crayfish and its adaptation to its life	4	14833	13938	895
23	Worms and their adaptation to their life	3	13911	13901	10
24	Leaves and their work	6	13566	12619	947
25	Forests and their protection	4	12551	12199	352
26	Evolution	5	12217	11820	397
27	Protozoa. Paramoecium and amoeba	3	10703	9028	1675
28	Great men and the history of biology	4	9689	8957	732
29	Growth, development, chemical cycle, sex, etc.	6	8575	8575	......
30	Introductions. What is and why study biology?	5	6103	6103	......
31	Paracitism	1	5779	5749	30
32	Fruits and their work	2	4901	4876	25
33	Man in general	2	4505	4490	15
34	Higher mental processes. Habit, instinct, etc.	3	3676	3676	......
35	Human machine	2	3512	2999	513

While Table II gives us the average course it is necessary to study Table III in order to see the varieties of courses that go to make up this average. If the course is based on Bergen and Caldwell's "Botany" we have a purely botanical course which ignores animal forms except in so far as they are concerned with the plant life. However, the fact that there is a blank in this column or any other does not mean that there is nothing written on that subject in that book, it only shows that the material was not of sufficient importance to make a separate chapter of it. There is some discussion of evolution in respect to plants in this book but it makes up only a very small part of the book and since it is discussed in connection with the

different kinds of plants it does not appear in the table. There is more general biology taught than is indicated because of the interlocking of the topics. Since the tables show the tendency of, or the average, this slight discrepancy, due to the lack of a finer classification, does not become so apparent or important.

TABLE III. SHOWING THE CONTRIBUTION OF EACH BOOK TO THE AVERAGE.

No.	Text Topic.	B-C Bot Ch.	B-C Bot Words	H. Civic Ch.	H. Civic Words	H.-Essen. Ch.	H.-Essen. Words	L-K. Zool. Ch.	L-K. Zool. Words	G. Biol. Ch.	G. Biol. Words	P-H. Biol. Ch.	P-H. Biol. words.
1	Vertebrata			1	4715	1	12803	9	28280	1	1050	3	21161
2	Insects					1	4787	10	27945	4	5084	1	11049
3	Plant forms	8	36845	1	9463	1	4975						
4	Improvement envir.	4	28520	2	16378					5	6636		
5	Foods, dietetics			1	6313	1	6784			10	17945	2	8722
6	Health, disease	1	5340	1	7666	1	5877			2	2947	1	7343
7	Seeds	1	4140	2	7922	1	5628			2	1914	1	6862
8	Respiration			1	5936	1	5902			7	10340	1	4666
9	Classification	3	17100							3	1575	3	5356
10	Nervous system					1	6595			7	8928	1	7410
11	Stem			1	2008	1	4190			3	13140	1	3265
12	Metazoa			1	6314	1	4190	3	10780				
13	Molluscs					1	2100	2	9965	3	4463	1	4739
14	Plant-human			1	10175	1	4618					1	6046
15	Flowers	2	5390			1	4876			3	3503	1	7032
16	Blood			1	4509	1	5167			5	7088	1	3678
17	Digestion			1	5093	1	4461			1	2925	1	7110
18	Environment			1	2102	1	3344			6	6188	1	5740
19	Roots	1	3960	1	3455	1	4600			3	3675	1	2149
20	Living things	1	4050	1	3205	1	2996			4	3854	1	1454
21	Plant-animal	1	6030	2	7377	1	1478						
22	Crayfish					1	3972	2	8500			1	3351
23	Worms					1	2936	2	10975				
24	Leaves			1	3255	1	5003			3	3582	1	1726
25	Forests	1	4680	1	2953	1	2554			1	2364		
26	Evolution							2	7867				
27	Protozoa			1	2102	1	2838	1	3230			1	2533
28	History			1	3130			1	4335	1	1488	1	1536
29	Growth									6	8575		
30	Introductions	1	1080	1	1529	1	1296			1	1138	1	1060
31	Paracitism					1	5779						
32	Fruits					1	4026			1	875		
33	Man					1	3454			1	1050		
34	Mental processes									3	3676		
35	Man-machine			1	1878							1	1634

The two Hunter texts and Gruenberg's text represent the average course. They treat almost all of the different topics in the table and follow somewhat the same relative sequence as is given in the average. The book of Linnville and Kelley, as was indicated before, stresses the animals in preference to the plants, although it ranks fourth according to the number of cities using it.

This indicates the varieties of courses that are given in the different parts of the country in the biology departments and indicates what would be an average course as well as how some of the typical courses deviate from this average. While this paper presents the results of an analysis of only six of the sixty-nine books reported by the fifty-nine cities, it does represent about seventy-five per cent of the courses. This situation is indicated by Table IV which enumerates the first twenty-five books.[2] The other forty-seven were given as reference books and

reported by only one city each. Had the data been gathered from the first twenty-five of the texts excluding the laboratory manuals the topic headings would have remained much the same and the sequence would not have changed to any considerable extent.

TABLE IV. TEXT BOOKS CLASSED ACCORDING TO THE NUMBER OF CITIES USING THEM.

No. of cities using	Book No.	Author and Title.
20	1	Bergen and Caldwell, Botany
14	2	Hunter, Civic Biology
13	3	Hunter, Essentials of Biology.
10	4	Linnville and Kelley, General Zoology.
8	5	Gruenberg, Biology
8	6	Peabody and Hunt, Elementary Biology
7	7	Conn and Buddington, Physiology
6	8	Davenport, Elements of Biology
6	9	Jordan and Heath, Animal Studies
6	10	Coulter, Plant Studies.
6	11	Hegner, Practical Zoology
6	12	Sharp, Laboratory Manual.
6	13	Hough and Sedgwick, Human Physiology.
5	14	Hunter, Laboratory Manual.
5	15	Bailey, Botany.
4	16	Bergen and Davis, Botany.
4	17	Coulton and Murbach, Briefer Physiology and Hygiene
4	18	Andrews, Practical Course in Botany.
3	19	Hodge and Dawson, Civic Biology.
3	20	Smallwood, Biology.
2	21	Eddy, General Physiology.
2	22	Hunter, elements of Biology.
2	23	Gager, Fundamentals of Botany.
2	24	Kellog and Douane, Practical Zoology.
2	25	Transeaus, Science of Plant Life.

[2]The writer wishes to express his appreciation of the kind co-operation of the following publishers who furnished the books mentioned for use in this analysis: American Book Company for the two Hunter texts, Ginn and Company for the Gruenberg text, and Macmillan for the Peabody and Hunt text.

AN ERRONEOUS EXPERIMENT IN GASEOUS DIFFUSION.

By Edward Condon,

Drew's Coaching School, San Francisco, Calif.

The presentation of the reaction between ammonia and hydrochloric acid gases as an illustration of gaseous diffusion, though in fairly widespread use, is erroneous, and it is the purpose of this brief note to direct attention to this improper demonstration. The experiment is given in at least one well-known high school physics text and is often used by high school and college instructors.

The experiment consists in placing two bottles, one filled with ammonia and the other with hydrochloric acid gas, mouth to mouth, though separated by a glass plate. Upon withdrawing the glass plate, the two gases come in contact. Their *diffusion* into each other is then said to be evidenced by the formation of a white cloud of ammonium chloride. The result at the end of the experiment is a dense smoke of ammonium chloride which fills both bottles.

Diffusion may be defined as the phenomenon resulting from that property of a gas by virtue of which it tends to equalize its partial pressure in all parts of the containing vessel. It is thus merely an extension, to the case of partial pressures in a mixture of gases, of the property usually used to define the gaseous state, i. e., that the substance expands to fill its container with a uniform density distribution. This definition is consistent with those usually given and obviously rules out the case where chemical action intervenes to alter the concentrations of the diffusing gases. Watson, in his "Textbook of Physics," definitely makes this stipulation.

Those who have performed the experiment know that the "diffusion" takes place within a fraction of a second even when liter beakers are used. The speed of the action is thus much greater than if it were a case of genuine diffusion. Diffusion data are hard to obtain but I have based some rough figures on a result given in Poynting and Thomson's "Textbook of Physics" volume 1, page 197. An experiment is described in which "carbonic acid was poured into a vertical cylinder 57 cm. high until it filled one-tenth of the cylinder. The upper nine-tenths of the vessel was filled with air and the gases left to diffuse. They were very approximately uniformly distributed throughout the cylinder after the lapse of about two hours." In the ammonium chloride experiment, the conditions are considerably

different. Ammonia and hydrochloric acid are respectively less dense than air and carbon dioxide which would make the true diffusion more rapid, if it were possible at all. The size of the cylinder used in the quoted experiment is not given and the effect of starting with an initial 1:9 volume ratio of gases instead of 1:1 ratio cannot be easily estimated. It seems plausible, however, that these differences would not make the hypothetical ammonia and hydrochloric acid diffusion take place with the great rapidity with which the reaction takes place in the main experiment under discussion.

There are two effects which have a part in making the speed of the reaction so much greater than we would expect natural diffusion to be. One is the volume change taking place:

$$\underset{(1\ \text{vol.})}{NH_3} + \underset{(1\ \text{vol.})}{HCl} = \underset{(\text{solid})}{NH_4Cl}$$

The volume of the solid formed from two volumes of reacting gas is negligible, so that unless the bottles leak at their point of connection, there will be an enormous reduction of pressure which will take place during the action in such a way as greatly to enhance the speed of reaction. If the bottles do leak, enough air will be sucked in to set up currents which will speed up the actions.

The other effect is the heat change during the reaction. The heat of formation of a gram-molecule of ammonium chloride from ammonia and hydrochloric acid is about 40,000 calories. If liter beakers are used, then under ordinary conditions the quantity involved is somewhat under a twentieth of a mol; but even in this case approximately 2000 calories of heat will be liberated. This will cause considerable temperature change during the reaction with a resulting stimulation of currents and increase of speed.

It is thus seen that the experiment neither illustrates the real phenomenon of diffusion nor gives a correct impression of the true rapidity of the diffusion of gases. One instructor to whom the error was pointed out has attempted to justify the experiment by saying that in practice the gases used are rather dilute mixtures of ammonia and hydrochloric acid gas and that these gases merely serve as *indicators* by their reaction to show the diffusion of one sample of air into another. This can hardly be accepted since, from the nature of diffusion, two samples of the same gas under the same conditions do not progressively diffuse into each other. The experiment, it seems, had best be completely eliminated from our physics teaching.

WHAT MAKES THE COURSE IN GENERAL SCIENCE WORTH WHILE?[1]

By W. F. Roecker,
Boys' Technical High School, Milwaukee, Wis.

Two generations ago Herbert Spencer propounded the question: What knowledge is of most worth? He answered it sweepingly in favor of SCIENCE, the field of knowledge then most neglected in schools. Although this was a very one-sided position to take in education, developments in invention, research, transportation, communication and industrial processes indicate that many of Spencer's assertions were timely and significant, if not prophetic.

Today the sciences occupy an important place in the curriculum. They have grown and spread so rapidly that repeated reorganization has been necessary. At present the great value of science as a part of an education is freely conceded. Our problem now is to perfect the organization of our science courses so that their content may keep abreast of the times and that the essentials of each course may be presented so as to make it truly worthwhile.

General science is the youngest of our high school sciences. Fifteen years ago it was unknown in most schools. In 1913 the writer made an inquiry into the status of this subject in Wisconsin, an account of which is found in School Science and Mathematics, Volume 14. At that time about one-third of the high schools in Wisconsin offered general science in some form. Today it is found in every school and for some time the state department of education has mentioned the subject as a regular part in the course of study of all accredited high schools. Current articles referring to general science indicate that similar progress has been made in most states. In fact the subject appears to be at the very peak of its popularity wave.

Those who witnessed the entrance of this subject into the curriculum know how its merits were questioned by many teachers who were devoted to the regular traditional sciences. Even now we find some who feel free to state that this subject lacks the earmarks of a science; it is looked upon by them as "tid-bit science," a sort of scientific hash lacking that organization and unity which characterizes every true science. In spite of this it must be admitted that the introduction of general science has been very rapid. Those who taught it have not argued very extensively for their subject but have taught busily and with

[1]Read before the General Science section of the Central Association Science and Mathematics Teachers at Hyde Park High School, Chicago, December 1, 1922.

enthusiasm so that gradually the subject has assumed a more definite organization and has also gained a more cordial reception from teachers of other sciences.

However, it is not the speed or the alacrity with which a subject is introduced that lends it significance; its true merit will be defined by the manner in which it continues to hold its position and the lasting effect it has on those who take it. This test of permanence based on enduring values is taking place now and the near future will tell whether or not general science will be able ultimately to take its place among other sciences and remain on a par with them in the curriculum.

It is very evident that this period during which general science has gained recognition must of necessity have been the occasion for reorganization. In this work the committees of the N. E. A. on the Reorganization of Secondary Education have been leaders. Their reports have emphasized the importance of defining objectives of the several sciences and of determining the specific values of science study. To follow up, develop and crystallize the work of these committees seems to be our special problem at present. As soon as we have made our aims quite clear and definite, as soon as we have learned what specific values we may look for in the subject, we may hope to organize general science courses that will be recognized as having the definite standards of the traditional sciences.

Objectives and specific values overlap, much as ideals and attainment do; the former may be outlined by those who teach and supervise, the latter will be largely defined by the interests of the learner and by personal and social needs.

A careful survey of objectives now seriously considered for general science indicates that they may be classed under three primary aims, under each of which may be grouped a number of minor objectives.

1. General intelligence on scientific matters as reflected in a body of functional knowledge.

2. Intelligent citizenship as shown in the solving of home and community problems.

3. Increased mental aptitude and capacity to solve problematic situations scientifically.

These broad aims include a number of items of special value; items which make general science conspicuously worth while.

(1) Orientation in the field of science is one of the great assets in later life; it gives the opportunity to get the "all around

look." This is the day of specialization; unfortunate is the individual who does not specialize wisely, or who handicaps himself with too weak and too narrow a foundation for his specialty. The occasion to discover talent among science students is most opportune in the general science class. Here the pupil may find himself. Schools of a technical or industrial nature follow the plan of giving the learner a taste of several elementary trades in order to make him see more clearly what his choice as a permanent trade shall be. In like manner, we do not know which student will be the future authority on butterflies but we owe every student the opportunity to ascertain where his deepest interests lie and what his greatest capacities are. Assuming even that no further sciences may be taken up by the student should he be obliged to leave school for the industrial world, he will have a breadth of view and the choice of an avocation which will prove invaluable to him.

Courses in general science and corresponding syllabi and texts, therefore, should be broad in scope; they should cover a wide field. They should map out a cross-section of the various sciences and lead the student to its most prominent peaks in order that he may appreciate that every science contains some great essentials; and from these high points should be offered as wide and as clear a vision of the scientific landscape as possible. General science belongs in the junior high school; its aim should be for breadth rather than depth. The intelligent outlook which it affords is especially worth while.

(2) To cultivate the power of organizing and systematizing the various divisions and units which present themselves in a survey of science and to learn to focus upon essentials and state them clearly as principles, laws, processes, or useful facts is as essential in the study of general science as in any other subject. In a field covering so wide a range of knowledge it would be unfortunate if the work could not be unified about a number of definite thought groups each having a natural setting. For this purpose it is not advisable, nor is it necessary, to take sections of the old sciences and strip them to the bone. Juvenile interest in skeletons of science is very limited. Furthermore, such an arrangement gives only vertical continuity within a given subject and omits entirely those horizontal lines of connection between the phenomena of the various sciences which give to nature its aspect of unity.

The greatest problem for those organizing courses in general

science or writing corresponding texts has been to organize the work so as to make it truly general in its content and at the same time to maintain such a reasonable unity about a number of focal points as to give the subject even the semblance of a science. This difficulty has led some teachers to accept the idea that the unity or mode of related thought may be neglected. We thus have courses and texts that could best be characterized as miscellaneous science; in some cases it might even be fair to call it vaudeville science. Such a course lacks one of the great and worthwhile elements of any course in education, more especially of a course in science. General science should be built up of a number of natural units, literally carved out of the environment, and each of these units should consist of an organized system of thought capable of leaving with the student a valuable residuum of fundmentals. Recent texts approximate this standard to a very gratifying degree.

No unit in general science, be it ever so interesting and pursued in the most spontaneous manner, will have the essential value it should have, unless it is so arranged and developed as to point to some great essential. This may be done by introducing the work with a statement of the fundamental points that are about to be worked out; it may be done by a skillful summary; it may be made the focal point of a demonstration, or a class room exercise; it matters not how, but it must be done. When general science gives to the student a limited number of facts and principles which are essential anchors in the field of scientific thought and experience it has fulfilled one of its essential functions that make it worth while.

(3) To arouse and satisfy a great variety of interests of the young student of science is the distinct province of general science. For this purpose many projects may be used as auxiliary to the regular class work. By putting these interests to active work many superficial inclinations are eliminated. By careful guidance rainbow chasing may be discouraged; at the same time dominant interests may be discovered and fostered. The tremendous significance of this phase of general science can not be overestimated for every student is a latent genius. The rock collector is the coming geologist or mining engineer, and should he, perchance, finally become a farmer he will be a better one for it. It is true that this auxiliary work can not displace the regular work of the course, but it is also equally true that no regular course can adequately take care of the individual interests of

the young science student. To discover the unpolished gem in the class room is distinctly worthwhile; in fact, to guide a student nearer to his life work or to an abiding avocation is an achievement.

(4) The subject of general science is a wonderful field in which to develop mental acumen. A large number of questions arise which test and develop that peculiar attribute of the mind known as common sense. Always ready to answer and usually in a very superficial manner, the beginner soon learns that sound conclusions come from reflective thinking. Why should a boy say, "A brick sinks in water because it is heavier than an equal weight of water?" The only thing that will stop such statements is an improved habit of thinking. And this habit will be invaluable throughout life.

Much of the class work consists in disposing of a situation of a problematical nature. To develop facility and aggressiveness in disposing of such problems is most valuable training and this quality in the mentality of any individual is highly prized in occupational life. The initiative which can be developed by having students assist in demonstration work may be the most worthwhile thing the student gets out of his course. Of all types of superficial thinking the worst is probably the gentle art of reasoning in a circle, or of drawing an irrelevant conclusion with sublime satisfaction. Discussions on how a submarine rises, or how an electric bell rings, are bound in time to develop a skill of seeing situations clearly and correctly and of cultivating a mental alertness which derives pleasure in striking at the heart of a thing by systematic processes. The devotion with which some students cling to false or irrelevant conclusions would lead one to believe that we can even contribute to mental honesty by the training given in this science work.

The world puts a high premium on the efficient thinker. If the work in general science gives the student this mental acumen in some measure before leaving school it has been decidedly worth while.

(5) The fundamental influence of general science is hardly complete unless it leads to a liberal reading of scientific literature. The average youth undoubtedly does considerable reading today, but the quality of it can be much improved. The suggestion and guidance of the teacher can open up a new world to every student in his supplementary reading. Many a youth finds the language and philosophy of the science text unattractive so that

his interest lags and even his daily preparation becomes irksome. For such there is available ample reading material, carrying the message of science in a commendable literary style.

Here is a great opportunity for cooperation between the English and the Science departments. A reading list which will satisfy the standards of both scientific and literary training is perfectly feasible; it is a great help in general science work for it frequently stimulates the backward pupil to better performance and it widens the interest and viewpoint of every student who uses it. Such books as Burns' Story of Great Inventions, Slosson's Creative Chemistry, Fabre's Insect Book, and Downing's The Third and Fourth Generation are typical of what such a list may contain.

There is such a wealth of reading material now in the form of papers, magazines and books that it is quite essential to save time and use discrimination in the reading that is done. Some very poor students are addicted to excessive reading, usually of a very superficial kind. They seem to long continuously for the mental tickle of scientific adventure and the vacant restfulness of a reading repose. Their mind travels in the mythical realms of a scientific dreamland. If such can be weaned from their aimless drifting by substituting a sense of discrimination and the zest which grows out of the pursuit of some constructive thought they will owe much to their experience in general science. For the average student the capacity to scan the scientific literature quickly and with a wholesome selective power is of great value.

A Milwaukee newspaper of December 1, 1922, contains the following article on the front page:

Changes Heads.

Paris.—Walter Finkler, Vienese biologist, has succeeded in transplanting the heads of insects. . . . The Matin adds: "This discovery is so astonishing that before discussing it we must make all possible reserves.

"Finkler took a series of insects—butterflies and caterpillars—and with fine scissors cut their heads off. He then immediately grafted these heads onto other insects. After a few weeks the insects operated on began to recover, but to the intense surprise of the professor the newly formed insects began in every case to assume the characteristics of the heads which had been grafted onto them.

"Bodies lost their original color and took the color of the insect

whose head they were wearing. A female insect onto which a male head had been grafted became a male."

Now, this is perfectly wonderful, if true. Verily, let us be careful how we read, lest we lose our heads.

A misprint in one of a set of objectives recently circulated for study aptly states a part of our problem as follows: "to read with greater understanding, literature which contains scientific *illusions*." If the course in general science can cultivate such a discriminative sense of reading that scientific illusions will be properly exposed it will have done much; for the average student the skill of scanning a wide range of literature and of selecting essentials from it wisely is of paramount importance.

(6) There is a portion of the work in general science which can be profitably directed to the problems of personal and public health and to problems of municipal welfare. Personal health is a pearl of great price; a disposition to contribute to the problems of public welfare when backed by the proper scientific insight is an expression of the highest type of citizenship. Problems and projects covering this field have been liberally outlined in recent texts. These cultivate an appreciation and an understanding of how essential the application of science is in the solution of municipal and social problems. This implies that the enlightened citizen must assume social obligations and show a disposition to participate in performing the duties which citizenship imposes. General science can here contribute very materially to good citizenship.

(7) Finally, the course in general science should develop an optimistic personality through the impress of subject-matter and the character of the teacher. To go to nature as an open book, to meet all situations in an open-minded and unbiased way, to search for the truth in obscure places, to appreciate the hardships of the early pioneers in science, to have faith in the progress of the future, these are some of the incommensurable elements that enter into a general science course. In one sense, this subject is merely a mode of teaching science. We must learn to carry old wine in new vessels. The student who likes this work is the one who likes to do things and to help others do them; he likes the leisurely freedom of traveling from one grand division of science to the other without paying heavy duties at the boundary; he likes the consideration he gets for his hobbies; he likes it because there is no limit to the questions he may ask; he likes it because of common enthusiasm about uncommon things; he likes it because the teacher illumines his subject.

How can we transmit the message of this subject without the personality of the teacher? We need teachers with the best preparation, successful experience, wide sympathies and great enthusiasm. A well organized course may provide for the all-around look but it is only the magic touch of the teacher that will inspire the upward look.

To sum up, then, we will teach general science with the best objectives we can select—but ultimately we will measure the true worth of our work by its effect on the learner.

A wide perspective of the field of science, the acquisition of a residuum of fundamentals, cultivation of many interests, development of mental acumen, a discriminative reading habit, a practical conception of citizenship and an optimistic view of scientific progress, these are some of the values that will be treasured by those who go forth to make a success of life after we have had them in our care.

If general science will in some measure cause these values to function in the lives of those who take it, the coming generation will rise and call us blessed.

GEOLOGY OF THE EL DORADO OIL FIELD, ARKANSAS.

A report on the geology of the El Dorado oil field, in southern Arkansas, that should be of value both to producers of oil and geologists has just been published by the United States Geological Survey as Bulletin 736-H.

Previous publications by this bureau have announced the identification of producing sands, have discussed the stratigraphy of the region west of the El Dorado field, have given reasons for the failure of some of the wells drilled in that territory, and have described the geologic structure of the northern part of the El Dorado field, showing that the oil in this field does not occur on anticlines, where it is generally found in other fields.

The report gives the results of an examination made by James Gilluly and K. C. Heald of drill cuttings from one of the wells in the field. The examination enabled the geologists to subdivide the formations above the producing sand into ten zones, which can be distinguished by carefully watching the drill cuttings as the drilling progresses, so that the approximate position of the bottom of the hole with respect to the oil sand can at all times be known. The lines of separation between certain of the zones are sharply marked. When the drill passes from the bottom of the Wilcox into the top of the Midway formation it goes from very sandy beds into beds that are only slightly sandy. The point of contact between the Midway and the Arkadelphia formation is also sharp and is easily detected, for at this point the drill passes from beds containing much sand and some limestone into beds that consists dominantly of shale or gumbo. The contact between the Wilcox and the Midway should be carefully noted, for oil or gas may be encountered anywhere below it, and a constant lookout for showings should be maintained after the Midway has been reached.

THE USE OF MOTION PICTURES IN TEACHING GENERAL SCIENCE.

BY IRA C. DAVIS,

University High School, Madison, Wisconsin.

Many efforts have been made to redirect, enrich and otherwise improve our courses in general science. We constantly hear the argument made that everything should be presented in a practical way. Can we by the use of motion pictures teach general science better than it has been taught in the past? Can we by the use of films better fulfil the recommendations given by the committee on Reorganization of Science?

"The 'hearing of lessons,' memoriter repetition of facts and principles gleaned from the textbook, the more or less discontinuous dialogues between teacher and individual pupil should give place to a real class discussion in which all take an active part in contributing, organizing and using the information dealt with. In such discussions the teacher serves to direct, stimulate, and advise. There should be a maximum opportunity for self-expression in the immediate problems."

Many kinds of materials have been adapted to film presentation. Pictures illustrating manufacturing processes of real products such as "The Making of Cotton Cloth," "The Making of Lumber," "The Manufacture of Steel." It would probably be impossible to present this material in any other form. It cannot be demonstrated in the laboratory with any degree of satisfaction nor can a pupil really understand the significance of such processes by reading about them in books. If the material in these pictures is presented scientifically, it ought to be a great aid in developing broader concepts of the value of science in our industrial processes.

We have films presenting imaginary and synthetic processes and films that give explanations of theories. "The Birth of the Earth," "The Origin of Coal," "How Life Begins," and "Beyond the Microscope" are some of the films that are used for these purposes. Many of these films are not entirely accurate, scientifically, nor do they agree with some of the modern conceptions of the nature of matter. There is a big field for development here. These theories or processes cannot be demonstrated in the laboratory nor can words give an accurate enough description of them for the boys and girls that are studying general science. If we attempt to explain natural phenomena, we cannot proceed very far without the use of some

theory. The only way to present these theories graphically is by the use of the motion picture or pictograph.

Films in the field of geography and nature study such as "The Yellowstone Park," "Thermopolis Hot Springs," "Birds and Animals," "Beautiful Flowers," present materials in a much more real and significant manner than can be done in any written description. In what ways can the wonders of nature be better presented than through the film?

Many of nature's processes are slow and tedious; the development and growth of plants requires a greater length of time than most classes in general science can spare. But through the use of the film, these processes can be speeded up so that the work of weeks or months required in the natural processes of development of plants may be shown in a few minutes by the use of the film. No doubt there is danger here in removing too far the connection between the natural processes and the methods used by the film, but I believe this can be safely guarded against in the proper presentation of the material.

The historical development of machines, the evolution of some of our manufacturing processes and the lives of our scientists are fields that the film could develop, but which have not been done to any extent so far. "The Life of Edison and his Achievements" is one film that has presented this feature of science. The development of the steam engine, the telephone, the gas engine, different methods of keeping time, the development of the electro-magnet could be presented very graphically by the use of the film and the pictograph. If there is any one phase of general science which we ought to emphasize more than any other, it is that of building in the pupil's mind the principle that there has been a general development in all types of machines—that no present day machine was perfected at once. I do not know of any means so effective for demonstrating the development or changes in science, as well as the film. What would be a better method of teaching than leaving with the pupil the possibilities that lie ahead in the development of any of these machines? The new film on Radio tells us how to construct and set up a radio set, but it does not attempt to demonstrate what the radio might mean to us five or ten years from now.

There are many films in the field of chemistry and physics that could be adapted for use in general science. Physical and chemical changes can be demonstrated in the laboratory quite

satisfactorily, yet there are some aspects of these changes that can better be presented through the use of the film. "Crystallization," "How We Hear," "Formation of Dew," " Through Life's Windows," "The Smelting of Iron" are some of the films of this type. We can demonstrate the formation of crystals in the laboratory and the pupil can see that crystals have been formed, but does he understand just how these crystals were built up? The film can present this in a very realistic manner. Here the film aids in developing the concepts of crystallization by continuing the work initiated in the laboratory. How we hear, how we see, how we breathe can be demonstrated in the laboratory, but the film can continue the work developed in the laboratory.

The film has far-reaching potential usefulness in geography, chemical and physical processes, development of theories and in manufacturing processes. The physiographic features, wonders of nature, river systems, cities, modes of living, etc., are presented in the film with high skill and incalculable value. The entire series of processes involved in the production of any one of many substances created by the chemist, and the phenomenal side of all sorts of revelations by other scientists, can be gripped up in a film and used either as a summarizing statement after study and experimentation or as a projected picture antedating an interesting adventure into some of these enticing fields. In either situation the film can be used to tremendous educational advantage.

We need some new types of films in order properly to develop or continue the problems instigated in the laboratory or classroom. Many of our present films waste a large portion of their teaching value through the use of non-essential material—material that does not have any direct connection with the most valuable parts of the film. The films were made to amuse rather than to teach. The new types of films can be arranged in three groups:

1. Films presenting situations to which pupils may react without so much information being furnished in the legends. Let the film ask questions.
2. Films of the problem-raising and problem-solving type.
3. Contrast films.

The ordinary film requires a mind that is receptive, passive, attentive—the mind that follows and approves. The new film will offer challenge, will give the mind data to work with, will develop a mind that projects itself ahead of the material in the film. There are practically no films of these types on the

market. The most practical method of developing them is by having general science teachers prepare the material for them.

In presenting situations in films to which pupils may react without too much information being furnished in the legends, it may be interesting to know that "The Department of Visual Instruction" of the University of Wisconsin has prepared films with this object in view. They have taken a film on electromagnetism and divided it into six lessons, each lesson in a unit by itself. The original film was literally cut to pieces and the new lessons built up in a very methodical manner. New legends were made, more to direct the pupil's thinking than to give him a large number of facts. The material in each lesson was definite; it could be easily connected with the laboratory demonstrations and classroom discussions, thereby enriching our whole teaching procedure.

In the second type of new film—the problem-raising and problem-solving type—we can set up a problem, give the mind facts to work with, and then by the use of these facts, solve the problem. We could raise the problem: What determines the power that can be developed by a dam? By the use of photographs and pictographs we could demonstrate how the height of the dam, the width of the dam, the distance the water is behind the dam, etc., might affect the amount of power developed by the dam. The pupils could solve the problem from the material presented in the film. There are scores of problems that could be solved by the use of the film. I simply mention the water power problem because it is rather difficult to demonstrate all phases of water pressure to classes in general science.

In the third type of new film—the contrast film—it will be possible to present all of the data on both sides of any problem and let the pupils decide for themselves what the correct solutions might be. We might, for example, develop a health program. On one side we could, by the use of photographs and pictographs, demonstrate the results of proper diets, good teeth, plenty of sleep, sufficient exercise, etc., while on the other side, we could demonstrate quite significantly the results of improper diet, lack of sleep, use of narcotics and stimulants, poor teeth, etc. From this array of facts, I am quite certain that pupils will not only arrive at more sane conclusions, but also their conclusions will become more permanent. The impressions created by the films will be more realistic to the pupils and the conclusions reached will be more apt to become a part of their daily life, than if the *same results* had been obtained by

reading a text-book or listening to the teacher telling them what not to do.

After having made a brief survey of the materials available for film presentation and having given recommendations for the new types of films, it is necessary to ask ourselves what technique shall be used in presenting these films.

The first consideration is the machine. There are many types on the market that are satisfactory. It ought to be possible to stop the machine quickly, reverse it easily and to change the speed without too much difficulty. By stopping and reversing the machine it makes it possible to get a reacting procedure and discussion from the pupils. To make the machine available for any teacher during any period of the day, it appears that the best plan is to train different pupils to run the machine during the different periods of the day. This gives the teacher abundant opportunity to direct the pupils in their discussions, while the mechanics of presenting the film is ably taken care of by the pupils.

The room for presenting the pictures should be darkened very easily. The room should be available during any period of the day, and the machine should be in such a position that it is always ready for use. The mechanics of presenting any film should require but very little time. The important thing is presenting the film, not getting ready to present it.

There are several methods in preparing the class for the films. It is sufficient briefly to outline the different methods that might be used.

1. The film can be given without any previous discussion. This might be the introduction to a new problem.
2. The film can be given to continue some theoretical discussion initiated in laboratory or classroom discussions.
3. The film can be a summarization of a group of processes, or it can follow the completion of some study.
4. We can have pupils prepare questions for the film to answer, either as a prepared topic, or one in which broadcasted information is given.
5. The film can take the place of some experimental work in the laboratory. Students could draw their conclusions from the facts presented in the films.

The types of films are important. The methods of presenting films are also important. But the most important factor in all of these is: What are the pupils doing while the film is being presented? The criticism against the motion picture on the ground that visual instruction makes no demand upon the audience to do any creative thinking is an indictment that may be lodged against other objective representations of reality.

The printed page is too often viewed with a high degree of passivity. The reader may be the victim of the dogma of acceptance, merely following the printed page with as little productive thinking as the person who follows the film presentation. The issue in all these situations is this: Does the individual behave as a recipient or a reacting agent? Is he a spectator or a participant?

The film should not necessarily aim to amuse the pupils nor should it give the impression that this is a day when no work is to be done. What can the teacher do to create the impression that the presentation of a film carries with it the notion that facts are to be gained, problems are to be solved, conclusions are to be drawn and applications are to be made?

Several different methods can be used to develop a reacting procedure in a class while the film is being presented. These given in outline form are:

1. Groups of pupils can prepare talks or lectures on the film. This is one method of distributing the work among the different members of the class.
2. Questions can be raised by the different members of the class and a general discussion might follow. The film could be stopped to make sure that all data are in hand.
3. The film can be stopped in order to have the mind anticipate what might follow. This will get attention forward.
4. Part of a film may be shown and then ask the class to consider what the remainder of the film might hold in store for them. In experimenting with a film on "The Yellowstone Park," after about half of the film had been presented, the pupils were asked to write what they thought the remainder of the film contained. They obtained all of the information they could from different sources. The next day when the remainder of the film was shown, the pupils were surprised to find what they considered the most interesting features of the park were not even presented in the film. This gives the pupils an opportunity to judge the value of the material presented in any films.
5. Pupils should be given the opportunity to question the accuracy of the film and the relative importance of the material presented. Many times it will be necessary to re-run parts of the film, to be sure all data are in hand.
6. Some teachers ask the pupils to take notes on the films. I doubt very much if this has any great value. It is difficult to take notes and watch the picture at the same time on account of poor illumination in the room.
7. If the legends in the film do not give too much information, we can ask the pupils to tell what the picture seeks to present. The film can be stopped frequently and a comparison of results made. Let the pupils develop a story or theory from the material presented without any information being furnished in the legends. This creates a great deal of interest among the pupils. It is also a basis for much valuable discussion.
8. Pupils can make lists of problems suggested by the films that have correlation with other studies. Many times some scientific facts will have a direct bearing on some phase of English, history, or mathematics. Occasionally teachers from different departments could group their classes for the presentation of a film.

Thus we see that there are many methods of having the

pupils react to the material in the films. Different types of pictures will require different methods, but there isn't any reason why we cannot teach pupils to think while they are seeing the pictures.

After the actual running of the film has been completed, we must ask ourselves: What can we do to continue the work that has been begun?

1. We can give a written or oral examination to the pupils, testing them for the facts and principles presented.
2. We can test the pupils for the theories presented. The theory should be developed in a logical order.
3. We can ask the pupils to schematize the problem as presented.
4. If the film did not present its material logically, or some of the pupils did not understand the principles developed, we could have each one of the pupils ask a few questions on the film. This would be an excellent method of humanizing it.
5. We could have the pupils test the accuracy of the film. This could be done by comparing the material presented in the film with facts as developed in the laboratory, classroom discussion or in reading books.
6. The film could be made the basis for a written summary. This would be an excellent opportunity to correlate the work of the science and English departments. The teacher of English might have some of his classes see the pictures with the general science classes.
7. The pupils could be asked to compare the film presentation with the linguistic presentation. Which presents its material more clearly?
8. In the problem-raising and problem-solving type of film, the pupils could begin the advanced study of the problem. The film would be only the beginning. The pupils would find it necessary to use other means to continue the study of the problem.
9. In the contrast type of film it will be necessary to have some discussion after the film has been presented. Each pupil should have an opportunity to present his conclusions to the class and have them give their judgment of the accuracy of the conclusions. Occasionally it would be necessary to have the pupils seek further information before attempting to make their conclusions.

No matter what method we use during or following the presentation of a film, the pupils should not get the impression that any film in itself is self-sufficient. A good film should always require further study of some kind. A film that simply attempts to amuse or present its material in a haphazard way is out of place in the classroom.

It is unfortunate that so few studies of the educational value of the film have been made. What are the experimental aspects or possibilities of the film? The argument we most often hear is that the film is a time-saving device. In what way is the film a time saving device? If we let pupils see motion pictures for a certain length of time and then have them make a record of the facts they have gained, and compare these results with what pupils can do by reading and discussion for the same length of time, we will find that there is very little difference in the amount of information gained by the two different methods.

However, the results vary greatly with different individuals and with different types of work. The poorer pupils seem to do much better in seeing the film than they do in reading a book. This may be one method of speeding up the poorer pupils to a realization of their responsibility. If we test these same pupils for the same facts some time later, we find that the film seems to have made a more permanent impression. In other words, pupils remember facts better by "seeing" them than by reading about them. This in itself probably substantiates the argument that the film is a time-saving device.

Many types of problems can be presented by the use of the film in a much shorter time than they can be demonstrated in the laboratory. There is a film on the telephone that presents most of the facts in less than ten minutes. It presents all of the facts and principles that are ordinarily demonstrated in the laboratory. Very little demonstration could be done in the laboratory in less than one hour. Even though we have saved time, we ought to question ourselves as to whether a pupil would gain as much by seeing the film demonstration of the telephone as he would by actually handling the apparatus and materials he uses in the laboratory. As far as I know, no one has worked out this problem. We could make the same argument for the gas engine. The film presents very thoroughly all the principles involved in the operation of a gas engine in less than 30 minutes. We could do very little with the gas engine in the laboratory or classroom in the same length of time. It would be an interesting problem to decide what value each method has.

Another method of saving time would be to join different classes in general science or other classes in science. Some types of films could be presented to large groups as well as small groups. Then again classes in general science and English could meet together. The science film might be made the basis for their composition or themes. By seeing the film the English teacher could judge of the accuracy of the statements made in the compositions or themes. Classes in science and history could be grouped in the same way. The development of modern industrialism would be an excellent opportunity for the correlation of the work in the two departments.

An experiment was conducted at the University of Wisconsin on the use of the film in teaching facts and principles as compared with the ability of an experienced teacher and an inexperienced

teacher to teach the same facts and principles in the same length of time. Sixty pupils were divided into three groups of supposedly equal abilities. The divisions were based on the scholastic standings of the different pupils. The two teachers saw the presentation of the film and were also given an outline containing all of the material presented in the film. The teachers were given ample time to prepare their material for teaching their classes. The teachers could use any method they desired in teaching their classes. On the same day the three groups assembled in their respective rooms. The film, the experienced teacher and the inexperienced teacher, all three, "*taught*" the best they could for one hour. At the end of the allotted time, the three groups met in the same room, and were given an examination covering the facts presented in the film. The results obtained by the inexperienced teacher were much lower than those obtained by the film, while the results obtained by the experienced teacher were slightly higher than the film. It would be dangerous to jump to hasty conclusions. When the same methods were used on different groups, the results varied considerably. Hoewever, it seems to prove that the film can teach facts and develop principles as well as a poor teacher, but no one would maintain that the film ought to take the place of the teacher. Their purposes are entirely different.

In brief, the film can be used in the motivation and enrichment of ideas; it can be used in the promotion of creative thinking; it can arouse curiosity and it can develop the work spirit. The thing of most value in the film is its use in tieing up different techniques of teaching. The laboratory work, the reading of the textbook, class discussions, questions and problems can all be taught with more interest to teacher and pupil if teaching and learning are supplemented occasionally with good films.

THE EFFECTS OF NOT REQUIRING MATHEMATICS IN HIGH SCHOOLS.

By C. E. White,
New Concord, Ohio.

At the April meeting of the Ohio Section of the Mathematical Association of America, Chairman A. F. Yanney gave an address on "Some Aspects of the Mathematical Situation in Ohio." In the discussion, the writer told of some of his findings in West Virginia relative to the status of mathematics. The writer was then asked by the association to publish his findings. It was evidently the opinion of the association that the situation in Ohio might be improved if the educators of the state knew of the conditions existing in West Virginia.

Indeed, the best arguments that can be produced in opposition to theories that are not sound are to be found in the conditions that exist where these theories have been on trial for a period of a few years. For example, the best arguments that can be found against the social and political theories of Trostky and Lenine are to be found in the conditions that exist in Russia today. The writer believes that no better arguments against those theories that would eliminate mathematical requirements from our high schools can be found than in the conditions of the high schools of West Virginia brought about by the elimination of mathematical requirements from high school curricula.

The State Board of Education in West Virginia is given the power to determine minimum requirements in the high school curricula of the high schools in the non-independent districts. The Board in 1919 recommended for use in the high schools a course that was known as "the new high school course" which made all subjects elective except four years of English and one year of American history. Previous to the final action of the Board relative to the course, a member of the Board in reply to a protest which the writer had sent him in behalf of mathematics wrote: "I understand that our state university is going to follow the lead of other state universities and eliminate mathematics as a requirement for entrance." This leadership was won soon after the Board's action but I question if the majority of the faculty is proud of that leadership. The members of the State Board of Education are also regents of the State University.

In an effort to find an antidote for the situation in the state, the writer wrote the President of the National Mathematical Committee and told him of the conditions in the state and sug-

gested that the state be flooded with reprints of many excellent articles that have been written in defense of mathematics. The reply contained the advice that a mathematical section of the State Teachers' Association be organized. Dr. Eisland of the State University, was also so advised and largely through his efforts such an organization was effected at Fairmont, West Virginia, November, 1919.

To find out to what extent the new high school course had been adopted in the high schools and to learn the effects of such adoptions a committee of five was appointed by the Mathematical Section.

The purpose of this article is to tell of the findings of the writer as a member of that committee. He was not present at the next meeting of the Association and does not know the findings of the other members of that committee. The writer was assigned eleven counties in which to make inquiry and got replies to inquiries from thirty-two high schools of the first class.

Of the thirty-two high schools of the first class, the writer found that eighteen, more than one-half, did not require algebra and that twenty-two, more than two-thirds, did not require geometry. Of the eighteen high schools not requiring algebra or geometry, one, with an enrollment of seventy-eight pupils, had no pupil taking algebra or geometry; one, with an enrollment of forty-seven pupils, had two pupils taking algebra and no pupil taking geometry; one, with an enrollment of sixty pupils, had no pupil taking algebra and five taking geometry; one, with an enrollment of eighty pupils, had twelve, one-fourth of the freshman class, taking algebra and none taking geometry; one, with an enrollment of forty-one pupils, had no one taking algebra or geometry; five had four and one-half per cent in algebra classes and one and six-tenths per cent in geometry classes; eighteen had nineteen per cent of the total enrollment in algebra classes, nine per cent in geometry classes and two and three-tenths per cent in solid geometry and advanced algebra. The last percentages were much increased by conditions in two large high schools where the per cent of total enrollment in mathematics classes was much above the average; one of these schools offered a course called the college preparatory course, requiring mathematics and perhaps many of the students had not yet learned that they could enter the state university without mathematics; and the other was at the seat of the State University which emphasizes mathematics as a prerequisite for many of its courses.

The observation in regard to the last two high schools emphasizes the importance of colleges and universities maintaining right standards as to entrance requirements, not only to prevent poor educational standards in the high schools but also to prevent the tendency on the part of high school students to elect those subjects that are easy rather than those that have greatest value, in high schools where fundamental subjects are not required.

In dropping mathematical requirements for the high schools of Ohio it seems to be the opinion of the State Board that the entrance requirements of the colleges and universities of the state will cause a large per cent of the high school students to take mathematics but they fail to observe that such protection for the high schools can not last long, for, soon, certain colleges will be bidding for the graduates that have not taken these fundamental subjects in education in their high school course. In West Virginia, two years previous to the action of the State Board relative to mathematics, a college observing that a few independent high schools had eliminated mathematical requirements dropped mathematical requirements for entrance. The examination of over one hundred catalogues leads the writer to think that this college was the only co-educational college in the United States to make it possible for a student to graduate without elementary algebra or geometry.

If the so-called "new high school course" remains unchanged and if certain theories continue to determine the educational policies of the state, we may expect conditions relative to mathematical study and mathematical teaching in the state to get worse. An inquiry made now would probably show conditions much worse than the writer found them two years ago.

After writing the above paragraph,the writer was moved to write letters of inquiry to the principals of a few high schools in West Virginia. Twenty letters were written and sixteen replies were received. As two of the replies did not answer the question, "Is mathematics required for graduation from the high school?," the writer will give his findings relative to fourteen schools.

Seven of the fourteen schools required mathematics and seven do not require the subject. Forty-one per cent of the students in the seven schools requiring mathematics were in mathematics classes and seventeen per cent of the students of the schools that do not require mathematics were in mathematics classes. Five of those requiring mathematics had fifty per cent of the

students in mathematics classes and five of those not requiring mathematics had only ten per cent in mathematics classes. One, requiring mathematics, had 350 enrolled and 180 in mathematics, while one, not requiring mathematics, had 360 enrolled and only seventeen taking mathematics. Of those not requiring mathematics, one, with an enrollment of 85 students, had six in algebra and six in geometry; one, with an enrollment of 67 students, had none taking algebra and four taking geometry; one, with an enrollment of 75 students, had thirteen in algebra and none in geometry; one, with an enrollment of 143 students, had thirteen taking algebra and fifteen taking geometry; and one, with an enrollment of 360 students, had seventeen taking algebra and none taking geometry.

The situation in West Virginia relative to mathematics will make it more and more difficult as the school years pass to get competent teachers of mathematics for the high schools. A few years ago, a student said to me: "I entered college intending to major in mathematics, but I have learned that mathematics is non-transferable and in a few years there will be no demand for teachers of mathematics in the high schools; so, I have decided to take a course in agriculture at the State University." The writer did not give much weight to what he said for he knew that the student had taken work in education under two men who had malice for mathematics but the findings in the state indicate that his words were somewhat prophetic. That student did work in trigonometry in a class of forty-three students and the writer was informed that there were only nine students in trigonometry in that same college in 1921. The year 1918 or 1919, the writer observed that one-half the graduates of that year got positions to teach mathematics in high schools. Because of the encouragement given to the study of mathematics by the state and by the college, what will be the future contribution of the college to efficient mathematical teaching in the high schools?

It should be observed that a college may furnish a number of teachers of mathematics for the high schools without contributing much to the efficient teaching of mathematics. School officials too frequently employ teachers of mathematics without having sufficient evidence that the applicant is qualified to teach the subject—having a college degree is not sufficient evidence; having license unless that license has been obtained by examination is not sufficient evidence; having credit for work done in

college mathematics is not sufficient evidence unless it is known that a good quality of work was done, but a failure to take college mathematics while in college should be regarded as sufficient evidence of not being qualified, and thirty hours of education is not sufficient evidence. Certain school laws in Ohio and West Virginia, relative to license to teach, give more emphasis to so many hours' credit in education as a prerequisite for teaching mathematics than they give to the importance of knowing the subject to be taught. The writer does not think that training in education is so transferable and he does think that a teacher without such training who can make a grade of ninety-five on an examination in geometry, sufficiently difficult to determine one's ability in the subject, will in general teach geometry much better than the teacher who has sixty hours of credit in education and who only makes seventy on such an examination. In West Virginia and also in Ohio, a college graduate with so many hours' credit in education can without any examination, get license and frequently the writer has observed that such a license has enabled persons, that he would consider very incompetent to teach mathematics, to get positions to teach the subject in high schools of the first class. A teacher of twelve years' experience teaching high school mathematics entered the writer's class in college algebra but in a few weeks was advised to drop the subject because it was observed that he needed a year's work in elementary algebra to prepare him for college algebra. He was graduated that same year and taught mathematics the next. A student who had only had one year of elementary algebra and who did that work nine years ago was not admitted to the writer's class in college algebra this summer. He will teach high schools mathematics in Ohio next year. Because he has twenty-four hours of credit in education and because he passed an examination on seven subjects, not including mathematics, he has license to teach algebra and geometry. By means of such laws relative to license to teach West Virginia may be able to avoid granting emergency licenses to teach mathematics in the high schools but will not be able to avoid the incompetence of teachers.

At the expense of coherence the writer will supplement thought in the above paragraph with observations relative to the transfer of training in mathematics to the domain of education and of training in education to the domain of mathematics. Two men that the writer did work under in freshmen mathematics in

college became presidents of colleges. The President of the university that he entered was the ex-professor of mathematics in that institution. The man that he did most work under at the university afterward became State Superintendent of Schools, President of National Teachers' Association, and President of a State University. The man that he did most of his post-graduate work under in mathematics is now Dean of Liberal Arts in a large university. A man that he did some post graduate work under had been a college president. A few years ago, and probably at the present time, a State University graduate in Indiana could get a life state license by passing three examinations—one, an examination on five educational subjects. A mathematician whom the writer knows and who had not received one hour of credit for work done in education prepared to pass that one examination in less than two months' time and did work as teacher at the same time. These observations tend to show that there is a transfer from mathematics to education but even research does not show that there is a transfer from education to mathematics and the writer is unable to explain why certain school officials drop mathematical requirements in the high school on the ground that mathematics is non-transferable and hire teachers as if training in education had great transferable qualities. The writer refrains from writing more on the subject of transfer for this article was not intended to be argumentative, but expository.

The new high school course in West Virginia was first published in the Educator Journal of West Virginia, with this introductory sentence, "If I were a boy again, wouldn't I have a good time at school?" The findings in the state show that there are too many students doing that thing—having a good time at school without any thought of being able later in life to meet the entrance requirements of many colleges and universities; without any thought of meeting the prerequisite requirements for many practical and cultural courses; without any thought of what they might need later if they should wish to become a doctor, a civil engineer, a mechanical engineer, an electrical engineer, a mechanic, an officer in the Navy or Army, a draftsman, a chemist, a physicist, an architect, or an astronomer. Such schemes are well fitted to give children a good time at school and lead them to a bad time afterward. Such schemes make the services of the school less efficient for the practical services of the nation.

In 1919, the writer sent letters to officials in nineteen other states, inquiring as to the status of mathematics. The replies from these states indicated that mathematics is required in all the high schools of eleven states and that in each of the other eight states mathematics (in two states, geometry) was not required in a few high schools. The conditions in these states were probably similar to the conditions that then existed in Wisconsin. The State Supervisor of High Schools in Wisconsin wrote: "In very exceptional cases this department permits schools to organize courses of study in which this requirement is not included. Probably, ninety-seven per cent of the cases, school curricula are so formed as to include algebra and geometry for graduation. Our high school supervisors are now at work upon a revision of our course of study for the state. This new course strongly urges the inclusion of a requirement of algebra and geometry in each high school curriculum."

The last sentence of the above reply indicates a reaction in favor of mathematics in Wisconsin, indicates that the lessons the war taught were not being overlooked by the educators in that state. Those who believe in the strong fundamental subjects in education hope that there will be such a reaction in Ohio and West Virginia.

OUTPUT OF ALUMINUM INCREASES 25 PER CENT IN 1922.

The value of the new aluminum produced in the United States in 1922 as reported by the producers to J. M. Hill, of the United States Geological Survey, was $13,622,000, an increase of about 25 per cent over the value in 1921. During the first half of the year domestic aluminum was quoted at 20 cents a pound for 99 per cent grade; in August the price was raised one-tenth of a cent a pound, and on the passage of the tariff act it was raised to 23 cents a pound, where it remained during the rest of the year.

Figures showing the imports for the last three months of 1922, since the passage of the new tariff law, are not yet available. The imports of aluminum in crude form, scrap, and alloys of any kind in which aluminum is the material of chief value, for the first nine months of 1922 amounted to 31,482,893 pounds, as compared with 26,177,852 pounds for the corresponding period in 1921. Articles made of aluminum valued at $1,486,177 were imported during the first nine months of 1922, as compared with articles valued at $1,635,106 imported during the corresponding period of 1921.

In 1922 the exports from the United States included 1,538,079 pounds of ingot and scrap aluminum and alloys containing aluminum, 2,808,946 pounds of plates, sheets, bars, strips, and rods, and 4,548,939 pounds of manufactured articles. In 1921 the exports included 301,951 pounds of ingot, etc., 499,124 pounds of sheets, etc., and 2,307,782 pounds of manufactured articles.

AN EVALUATION OF STANDARD TESTS AND SUGGESTED USES IN IMPROVING PHYSICS TEACHING.

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Before attempting to discuss this subject let us agree on a few tentative definitions of terms. The term "standard tests" is often used rather loosely to include various tests for which in some cases no norms or standards have been established. Standard tests are generally supposed to have been scientifically devised but in some instances about the only evidence of science is that they have been printed. Some so-called standard tests are not worth the paper they are printed upon. But in the more restricted sense of the term "standard tests" are somewhat scientifically devised, are objective, and are designed to measure some characteristic, trait, or stage of achievement. By "objective" we mean such a test as can be scored, by any ordinary person of normal intelligence, without being influenced by the scorer or his personal knowledge of the individual who did the test. This means that the answers to the items included in the tests are very definite and exact and not depending upon the judgment or any of the subjective elements of the one doing the scoring. It has been shown by different investigations that the customary class-room examination paper will be given a wide variety of scores (or grades) when scored by a number of different teachers. Kelly [1] reports that marks assigned by 116 teachers ranged from 28 to 92. Furthermore, it has been shown that the same teacher scoring a set of papers on several different days will vary as much as 30% on the scores allowed to a given paper. Now if the test is objective this difficulty will be eliminated.

During the past ten years nearly every school administrator has enjoyed to some extent the fad of giving tests. Some tests are interesting and working on them is instructive and a good mental exercise for the individual. But too many times tests have been given and afterwards never even scored. Or if they are scored there is no use made of the results. The person giving the tests knew nothing about tests but wanted to be in vogue. He gave tests because others were doing it. Not so long ago it was quite the thing to have appendicitis but now glands are in vogue. Nowadays few people have their appendixes removed unless there is need for such an operation. We believe that in the near future we shall give tests only when there is a need for them and when we have a real purpose in giving them,

[1] F. J. Kelly, *Teachers' Marks*.

What are the purposes for giving tests? Of what value are standard tests or scales? The value of any test is directly proportional to its usefulness. We may use one or more tests to aid us in classifying pupils either in the high school or in the elementary school and group them in sections A, B, and C:—below average, average, and above average. In so doing we are able to provide for the bright boy or girl a much fuller treatment of subject matter, a much broader and richer experience, and so enable him to become a capable leader. We can also do better by those pupils below average by spending time only on the minimum essentials and giving simpler and more satisfactory explanations. Or, if it is not practicable to make two or more sections we may give tests in order to find out what is the extent or spread of individual differences in a given group and so be able to teach the group more satisfactorily. For without such information concerning a class the teacher will teach the bright pupils and go too fast for the slow ones, or he will explain fully and carefully for the slow pupils and make the class too slow and uninteresting for the bright.

Again, it is often worth while to give tests in order to compare one city system of schools with another, or others, or to compare schools in the same system, or to compare classes in the same building. This may be justified for either of two reasons: diagnosis or publicity.

We may be able to get definite information as to status then follow it up by further testing to discover the causes. These causes may be due to the degree of intelligence of pupils or environmental circumstances of home-life; they may be due to poor selection of subject matter or an improper emphasis on the various phases of the course of study; or they may be due to some deficiency in the physical conditions of the school plant and equipment; or *even* to lack of efficient teaching.

Publicity is one of the most important phases of school activity. It is essential that the public know the existing conditions and needs. To bring this about every one connected with the school should be pressed into service—boards, administrators, principals, supervisors, teachers, pupils, janitors, and even visitors. The results of testing may prove very valuable to stimulate public opinion by showing the needs in definite form.

Probably the most important service that can be obtained from the use of tests is provided through experimentation. There are many problems that should be answered which require

accurate measurement. Tests may be used in discovering the best methods of teaching, including: presentation of subject matter, repetition of drill with increasing intervals of time, and other various types of pupil-activity within the class-exercise.

Again we need to know the best order of studying the different parts of a given course of study. We need to know the best size of class for the maximum efficiency. We should know how much time is needed for any given course.

There are other good reasons for the use of standard tests. For example, they can be used in rating teachers, to stimulate effort on the part of teacher and pupils, to convince pupils of the need for drill, and to establish standards of achievement.

But in order to be effective in solving these problems the "standard tests" used must be *satisfactory* "standard tests." Let us consider briefly some of the more important criteria which a good test should meet in order to be satisfactory.

In the first place what does the test measure? Does the test really measure what we want to measure or does it measure some small portion of what we want? It is necessary to consider this point very carefully for, *actually*, tests may not measure what they were designed to measure. Any test measures only the ability to do that particular test. Of course this is indicative of ability to do similar things. This may involve many other items in addition to the thing we want to measure. For example, to do the majority of tests it is necessary to be able to read, comprehend, write, etc. In such cases we can only hope that part of the work required in the said tests does measure a part of the ability we wish to measure. Therefore it is important that this item be carefully considered.

Another important question is that of the reliability of the test. When testing a given group several times will we get the same score for the group? Are there equivalent forms? Will the different forms of the test prove to be equivalent and show the same results?

Again, is the test objective? Will the score obtained in the test be the same regardless of who does the scoring? Can several persons score a given paper and each of them assign the same score?

To fulfill this requirement it is necessary that there be an answer sheet giving the correct answer to each question. The answers must be definite and not depend upon the attitude or mood of the one who scores the paper. Furthermore the score

assigned to the paper should be independent of any personal knowledge of the individual who wrote the paper.

Another important consideration is that of administration of the tests. How much time is required to give the tests and is the plan of giving the tests satisfactory to the existing conditions? Is the scoring of the tests comparatively easy and simple or is it a considerable task? Can the scoring be done by the average teacher or is it too technical and otherwise difficult? And will the results of the testing be easily made available in usable form?

Are the tests interesting to the individuals who are to take them? Is the actual work involved a good mental exercise, conducive to mental development, and a good expenditure of time?

Again, will the cost of the tests and the administration of them be excessive or reasonable? We cannot expect to find any test which meets all these criteria in an ideal way. However, in selecting tests or scales we should consider them carefully concerning the satisfying of these six items:

(1) Does the test measure what we want measured?
(2) Is it reliable?
(3) Is it objective?
(4) Can it be easily administered?
(5) Is it interesting and not a waste of pupil's time?
(6) Is the cost reasonable?

But do all these considerations have anything for the teachers of physics? Yes, very decidedly so. There is perhaps no other subject which offers more problems for solution than that of hish school physics and to solve these problems we can use standard tests very advantageously. Many schools do not have classes in physics which are large enough to be classified and divided into groups of comparatively equal ability but we might well use tests to find out the extent of individual differences.

It would be well to include in such testing enough of a variety to get a thorough diagnosis of the members of any group. We may find some who cannot read understandingly and perhaps a greater number who do not know how to read problems. Some will not be able to do the four fundamentals of arithmetic well enough to do physics problems. The teacher should know the status quo of each member of the class. It is hardly necessary to say that knowledge of the facts should be followed up by remedial work.

But perhaps the most important use of tests in the field of physics teaching is for experimental purposes. We need them in order to carry on investigations in regard to the best methods

of presenting the subject matter. With the present methods there is no doubt that the customary course of study includes too much for a year course.

Should most of the time for recitations be used for questioning or should a good deal of the time be used for teaching? What portion of the time should be used for lectures and for demonstrations? How much time should be used for working problems in class? From the standpoint of efficiency is it justifiable to spend 4/7 of the time in doing laboratory experiments? Which method of handling the laboratory work is best? These are a few of the problems having to do with methods and the distribution of time.

We also need to determine the most satisfactory arrangement of subject matter and in what order the various elements of the course should be pursued. Upon which phases of the physics course should the emphasis be put? And what elements of subject matter should the course of study include? Is it advisable to have separate classes for boys and girls?

Also, we need to establish standards of achievement, those standards which *should* be reached as well as those that are being reached.

Of course we have our own personal opinions as to the answers to a number of these problems but what evidence have we to support such opinions? Perhaps scientific investigation would prove that such opinions are quite wrong. At any rate, they need to be supported by such evidence before we put too much confidence in them.

At present there are few, if any, satisfactory tests or scales for physics. We need more and better ones. Chapman's[2] tests in Electricity and Magnetism, and in Sound and Light partly meet the requirements for being satisfactory. And also the Iowa Physics Scales for Mechanics,[3] for Heat and for Electricity and Magnetism are now available at small cost.

One of the first problems which faces any one who would design a test for physics is a determination of the chief aims. We do not want to test on things which were never taught or considered to be aims or goals of achievement.

A careful investigation of the courses of study offered by North Central High Schools to discover the aims of science teaching has been made. Another study shows the aims of science teaching according to the composite personal judgments

[2]J. C. Chapman, Yale University, New Haven, Conn.

of more than one hundred science teachers. Combining the results of these two investigations we find the first five important aims in the order of their importance to be as follows:

1. To give knowledge of natural phenomena.
2. To serve as guide for daily life.
3. To give scientific attitude.
4. To prepare for college entrance.
5. To give familiarity with subject matter.

In designing the Iowa Physics Scales the first two of these were considered[4] to be the aims for teaching physics.

We have considered briefly the more important uses of "standard tests," namely

1. For purposes of classification.
2. To determine extent of individual differences.
3. To make comparisons, either for the purpose of diagnosis or to aid in publicity work.
4. For experimentation:
   (a) To improve the methods of teaching.
   (b) To determine best order of subject matter.
   (c) To find best size of classes for efficiency.
5. For rating teachers.
6. To stimulate effort on part of teacher and pupils.
7. To convince teacher and pupils of need for drill.
8. To establish standards.

And the following criteria have been suggested for careful consideration in selecting a *satisfactory* "standard test"—

1. What the test measures.
2. Its reliability.
3. Whether or not it is objective.
4. Ease of administration.
5. Interest and worth to pupils.
6. Cost.

A number of problems in the field of physics teaching have been mentioned as needing the assistance rendered by *satisfactory* "standard tests." Let us each contribute something toward improving the teaching of this subject. It is too important to be allowed to be shunned by so many of our high school pupils and ultimately to be dropped from the course of study. Is it worth the effort? Shall we begin immediately?

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[3]Extension Division State University of Iowa, Iowa City, Iowa.
[4]See "Scales for Measuring Results of Physics Teaching," University of Iowa Studies in Education, Volume 2, Number 2, Iowa City, Iowa.

CHARLES' LAW APPARATUS.

By G. E. Ripley

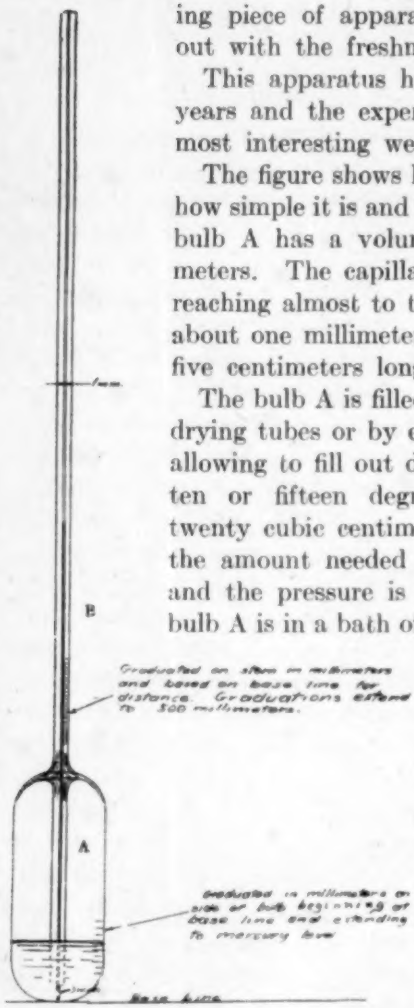
University of Arkansas, Fayetteville, Ark.

The use of Charles' Law in the absolute zero reasoning is so important that the writer considers it desirable to have the students in first year college physics test this law in the laboratory. Of the two coefficients of a gas the writer believes it better to test the pressure coefficient of a gas when the volume is kept constant than to test the volume coefficient when the pressure is kept constant. The first does not lead to any absurd line of reasoning as does the second which makes the volume of the gas zero when absolute zero is reached.

However when one begins to examine the apparatus now on the market for testing the proof of these two coefficients he at once finds that the difference in cost of the designs makes it desirable to use the second method. The apparatus for the determining of the volume coefficient of expansion of a gas at constant pressure is very simple and inexpensive. In fact any physics teacher can prepare this apparatus with little trouble and if this was all then the writer would prefer this experiment to the constant volume experiment. Simple as is the apparatus, the writer's experience over a short period of years has been that it is almost impossible to secure satisfactory results and keep the apparatus in good working conditions. The mercury thread is always giving trouble and separating just when one thinks "all is well."

In theory the apparatus for determining the pressure coefficient of a gas at constant volume is good and appears simple and easy to manipulate. It is only after one has had the experience of observing what happens when this apparatus is placed in the hands of first year physics students in college physics that the objections and defects become evident. Breaking of the capillary stem, allowing the mercury to be driven over into the bulb, breaking of the bulb in changing from ice to steam bath, leaking air at the joints and decay of the rubber tube and large loss of mercury from giving way of the tube.

Several years ago the writer began experimenting to see if a convenient inexpensive compact piece of apparatus could not be designed for this experiment, which would eliminate all chances for leakage, danger of mercury being driven over into the bulb and loss of mercury through loose joints. After many attempts and after different designs had been tried the follow-



ing piece of apparatus was developed and tried out with the freshman students.

This apparatus has now been in use for three years and the experiment has proved one of the most interesting we have in our first year work.

The figure shows how the apparatus is designed, how simple it is and how easy to manipulate. The bulb A has a volume of about 200 cubic centimeters. The capillary tube B sealed into A and reaching almost to the bottom of A has a bore of about one millimeter diameter and is about fifty-five centimeters long.

The bulb A is filled with dry air either by use of drying tubes or by exhausting with air pump and allowing to fill out doors when the temperature is ten or fifteen degrees below freezing. About twenty cubic centimeters of mercury is put in A, the amount needed may be carefully calculated, and the pressure is then increased so that when bulb A is in a bath of ice and water at zero degrees the mercury column will stand two or three centimeters above the top of bulb A. The pressure on the air in the bulb is then the barometric pressure plus the height of mercury in the tube. When the apparatus is placed in the steam bath the temperature of the air rapidly rises and this increased pressure drives the mercury up the tube thus holding the volume of the air constant in A. The expansion of the mercury, due to rise in temperature, not only takes care of the expansion of the bulb A but also compensates for the mercury driven up the tube B. As the temperature of the mercury in tube B above top of bulb A is not far from room temperature there is not much change in its density and therefore a correction for this is not necessary.

The pressure on the air at boiling point is of course the barometric pressure plus the height of the mercury column in tube B. On account of capillary depression of the mercury in tube

B at zero temperature of bulb and boiling point a correction must be added to the pressure of barometer plus mercury height in tube B.

The formulae for finding the pressure coefficient of a gas at constant volume with this apparatus is,

$$a = \frac{(B + h_t - d + c) - (B + h_o - d + c)}{(B + h_o - d + c)\ (t - t_o)}$$

where

a equals pressure coefficient of a gas at constant volume.
B equals barometric reading in centimeters.
h_t equals height of mercury in tube at boiling point, above table.
h_o equals height of mercury in tube at zero or t_o, above table.
c equals capillary correction for depression of mercury in tube B.
d equals height of mercury in bulb A, above table.
t equals temperature of steam at boiling point.
t_o equals temperature of ice and water mixture.

The following values of a with data obtained by students will show how accurate the results are and how closely the values check.

Trial 1.		Trial 2.		b Trial 3.	
h_o	= 13.00 cm.	h_o	= 13.1 cm.	h_o	= 13.02
h_t	= 44.40 cm.	h_t	= 44.41 cm.	h_t	= 44.42
t_o	= O C.	t_o	= O C.	t_o	= O C.
t	= 98.8 C.	t	= 99. C.	t	= 99 C.
B	= 72.86 cm.	B	= 72.89.	B	= 72.90.
c	= 1.2 cm.	c	= 1.2 cm.	c	= 1.20 cm.
d	= 1.3 cm.	d	= 1.3.cm.	d	= 1.3 cm.
a	= .00370.	a	= .003682.	a	= .003665.

Most of the values obtained for the pressure coefficient of a gas at constant volume run about like the above values. Hardly ever do we get values off over one per cent.

If desired the apparatus can be arranged to have the pressure at zero degrees equal to atmospheric pressure by inclining the tube so that when in the ice and water the lower end of the tube is open to the atmosphere. However, we have found it better to make the pressure great enough inside the tube so that the mercury stands up above the bulb a few centimeters when in the ice and water mixture. This insures dry air in the bulb.

The writer will be pleased to answer any questions concerning this apparatus which may not be covered in this short article. We expect to take up the consideration of change of density of the mercury and see if this is enough of an error to need correcting for in the determination of a.

THE HARMONOGRAPH AS A PROJECT IN HIGH SCHOOL PHYSICS.

By R. L. Doan,

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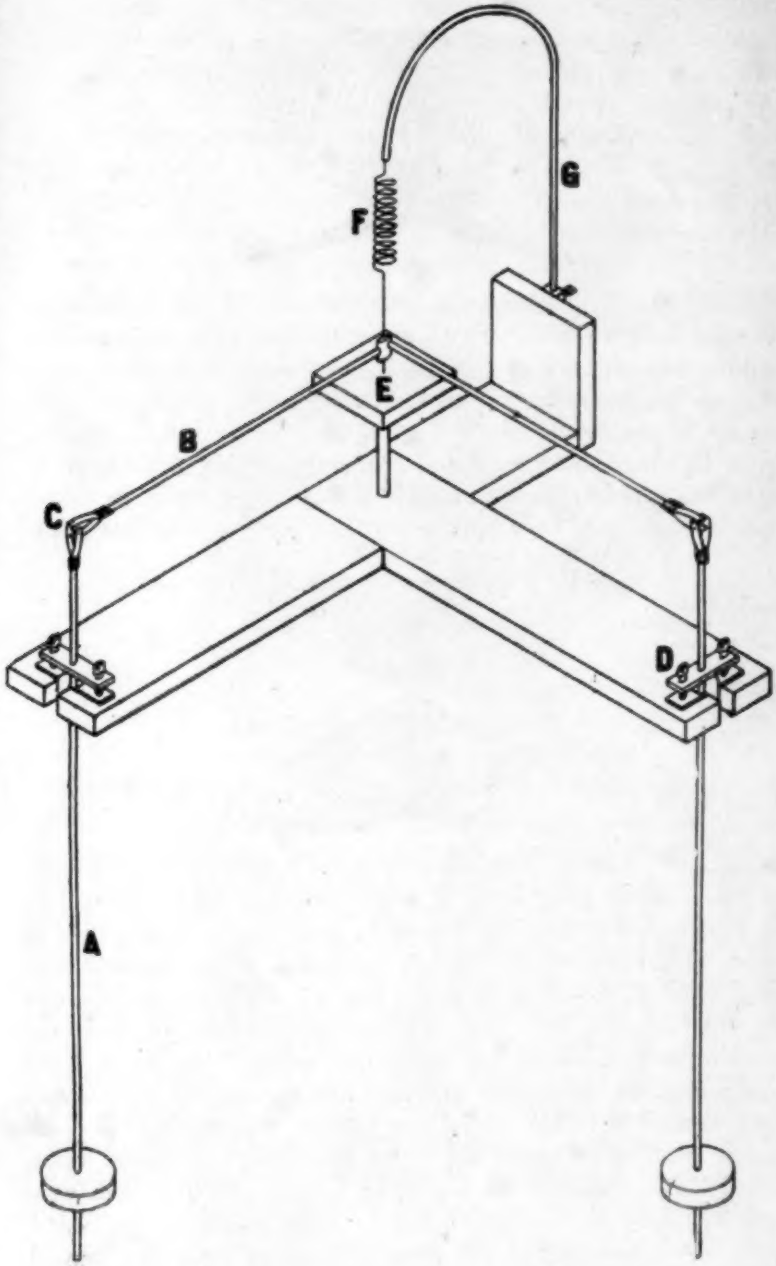
To teachers of physics who are looking for different ways of making the subject appeal to the interest and initiative of their pupils the following should prove of some value.

The harmonograph, as originated by Tisley in 1874, is a simple device for showing the resultant effect of a combination of two harmonic motions at right angles with one another. It is not at all new in itself nor is it by any means the only method of showing this effect. The Lissajous figures, obtained in several ways but more commonly by projecting a beam of light reflected in succession from two small mirrors mounted on the prongs of two tuning forks which are vibrating at right angles, are well known in this connection and are described in several elementary physics texts. (See Hopkins "Experimental Science" or Duff "Textbook on Physics," Fourth Edition). However, the results obtained by the use of the harmonograph are much more striking than the transitory figures gotten by any of the other methods and, in addition, permanent records may be made.

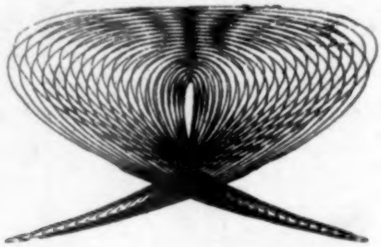
The instrument used in making the tracings shown in the accompanying illustrations, while it involves the same principles as the Tisley harmonograph, is of somewhat different construction. (Fig. 1.) It consists essentially of two pendulums, about 1¼ meters long mounted on steel points (D) so as to be free to oscillate only in planes at right angles to one another. An arm (B) is connected to the top of each pendulum rod by means of a universal joint (C) and extends to a central table. These arms are then joined to a small wooden block (E) in which a phonograph needle may be inserted. Freedom of motion at E may be obtained either by the use of another set of universal joints or by uniting the arm rods in a smooth-working "fingered" joint, letting the needle project through the center of the joint. The latter is to be preferred because of the tendency to buckle with the universal joints. Needle tracings are made on a smoked glass plate at E. The tension in the adjusting spring (F) is varied by raising or lowering the rod G, which should be at least a meter long for good results.

With the pendulums swinging through equal arcs with the same periods a straight line should be obtained if they are started in phase, or a unison circular spiral if they are started

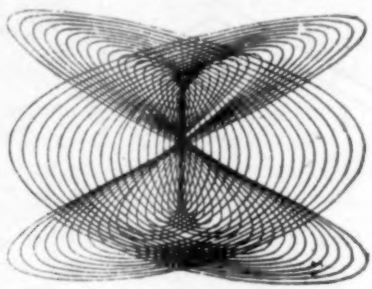
one-fourth of a period apart. The spiral effect is of course due to the frictional damping of the pendulums. In order to get



satisfactory results with this spiral it is necessary that the pendulums have exactly the same period and amplitude, so that they both come to rest at the same time.

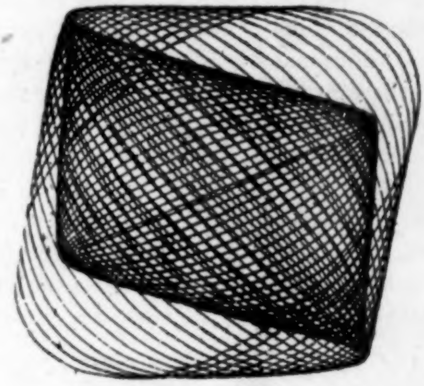


Now if one pendulum is left unaltered and the bob of the other is raised until it makes, say, three oscillations while the former is making two, either fig. 2 or fig. 3 is obtained, depending upon whether the pendulums were started in phase or slightly "off" phase. If one should plot this curve graphically on cross section paper he would find that in order to get a tracing of the type of fig. 3 it is necessary to start the pendulums with sufficient difference in phase that they both reach their central positions at the



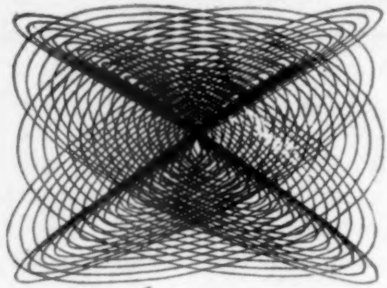
same time. An exact difference in phase is difficult to get simply by releasing the pendulums by hand, although more can be done in this direction than one would at first suppose. In order to secure the release of the second pendulum at any desired time with reference to the phase of the first the writer has made use of the following device. One rod was held back at its most extended position by placing the weight against the end of a bar electro-magnet, the circuit of which was arranged in such a way that contact with the energizing battery was made at a point in the path of swing of the other pendulum. A board about 3″x12″ was selected and a central portion one-half inch wide was cut away for about two-thirds of the length of the board. Then on either side of the groove a copper strip was placed,

and binding posts attached. This board was then clamped in such a position that the pendulum would swing back and forth through the central groove. Two little contact pieces were made by inserting short pieces of brass rods (less than 1/8″ dia.) into small round pieces of metal. One of these was placed on each metal strip and the contact made simply by bringing the tips of the rods together. This method of contact insured that when the pieces were once knocked apart by the initial swing of the pendulum, there was no further interference with its oscillations. It is evident that by moving these contact pieces up and down along the metal strips the pendulum held by the electro-magnet could be released at any point in the path of the other.

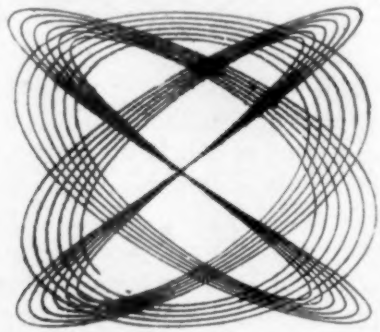


There are several period ratios which give characteristic figures but it is necessary that adjustments be exact if good results are expected. One exception to this is the tracing obtained by adjusting the weights for the unison spiral and then slightly raising one of them. The result is a slowly changing phase as shown in Figure 4. The only way that the correct lengths of the pendulums can be ascertained is by watching the successive oscillations and seeing if the swings come simultaneously at the time indicated by the ratio. If one gets a little ahead of the other even after thirty or forty oscillations, a slight shift must be made in the position of one of the weights. Obviously such a process is rather tedious but this factor may be cut down considerably if some device is provided whereby the weight may be raised or lowered just perceptibly and without the inconvenience and waste of time involved in working with the clamp tightening screw. This has been done in the instrument shown by cutting

threads on one rod for about two-thirds of its length. Running the weight platform up these threads gives an easy and quick method of adjustment.



It will be noticed that in every case the period ratio is indicated by the number of loops on adjacent sides of the tracing. Thus in Figure 5, obtained by adjusting the pendulum weights for a 5/4 ratio, there are five loops on one side and four on the other. An inspection of Figure 6 shows that it was made using a 4/3 ratio. H. C. Newton, in his book, "Harmonic Vibrations," calls attention to the fact that in the majority of cases the ratio of the vibration frequencies of the pendulums when a perfect figure is obtained, if applied to musical notes, will give a harmony. Likewise, discordant musical ratios will give unsymmetrical harmonograph tracings. There are some exceptions.



Needle tracings of all the above figures may be made on smoked glass plates (a candle flame is best for the smoking process) and with a little care may be "fixed" so as to make permanent records. A good fixing agent is one consisting of about two parts white shellac and ten of denatured alcohol. It is necessary to apply this with a very fine spray in order to avoid the displacement of small carbon particles. Even with the utmost care the plate will perhaps appear somewhat spotted. This is not so notice-

able until a photographic print is made, using the tracing as a negative. If one preferred to get the tracings in ink instead of on smoked glass, the block at E could be made so that a fountain pen might be inserted. In this case it is best to give the pen quite a bit of slant.

The harmonograph is so simple that it may easily be constructed in the ordinary school shop. There is no question about its proving of interest to the pupils because there is always that anticipation of the kind of figure to be obtained with a differen-period ratio. If any of the students in the class have had elementary trigonometry, or even mechanical drawing it would be an easy matter to plot curves representing given sets of conditions obtainable with the harmonograph. This is worked out in a more advanced way in the fourth edition of Duff's Physics. It is interesting to compare these graphic curves with the needle tracings.

THE EYES OF A CHILD.

I am brown, or blue, or black, or gray. I have faith in everyone and everything. I trust the world, I still possess the crystal clearness of innocence. I see nothing sordid or unlovely. The pictures I send to the baby brain are magical. I am not for sale—I cannot be bought—I am priceless!

I am sensitive. I require care and thought, but I grow weak with overwork or ill-health or strain. I resent indifference or neglect. When I am not as strong as I should be, I protest against over-exertion in the schoolroom, I rebel against long hours of study or reading at home where the lights are so dim that I cannot see.

I sound my warnings daily. I cause misery to the brain and a throbbing head. My punishment is relentless. I worry myself into aching, twitching, burning coals of fire. I cannot work—I cannot sleep—I can only weep. The parents of the baby body in which I dwell blame fretfulness, illness, apathy, dullness and stumbling gait, but, I am the cause. I fairly sing and dance and thrill with light and joy and gladness when I am healthy and strong and rested. If I need aid from the skilled men who know me, who study me, who give me what I must have, then I respond in sheer gratitude.

If I have behaved badly and have caused pain it is only because I have needed help. With the assistance these learned men can give me, I live until I am no longer wanted. I never return once I go. I go reluctantly if go I must. I speak that all parents may hear.

Remember, I am the eyes of a child!
I may be the eyes of your child!

Conserve the eyesight of your child. It is a duty you owe the child, yourself, the community, the state and the nation. But above all you owe it to your child.

NOTES ON HAWAIIAN BOTANY WITH SPECIAL REFERENCE TO THE FUNGI.

By F. L. Stevens.

Hawaiian botany as well as zoology is of especial interest for several reasons. The extreme isolation of the islands, which lie some 700 miles from any considerable islands and nearly 2,000 miles from continental land, renders the question of the origin of the flora an interesting and important problem. Some botanists see in the plant distribution evidence of previous land connection, of land bridges whereby the ancestors of the present flora and fauna arrived, while others explain the present condition as due to the wind and water currents, even going so far as to distinguish separate waves of migration correlated with the geologic record of America, the submergence of Panama, and the consequent changes in ocean currents. The islands are entirely volcanic; Kauai, the northernmost, is doubtless the oldest; Hawaii, the southernmost, doubtless the youngest. Only coral on lava or lava itself may be trod upon.

All of the islands have been repeatedly subject to lava overflows; Kauai long ago, Hawaii recently, perhaps today. These overflows have naturally profoundly influenced vegetation. In Kauai all has been quiet for ages and immense canyons have been cut in the once hot lava. On Hawaii many lava flows during the last century and countless ones earlier have solidified into stationary stone rivers, often 30 to 50 miles long by several miles wide. These flows of all ages on Hawaii and their eroded counterparts on Kauai give most fascinating fields for ecological study. The character of erosion has produced wonderful canyons, cliffs and gorges, and miles of knife-edge ridges with abrupt changes in elevation and sudden transitions in rainfall. The top of Mt. Waialeale, Kauai is the wettest place in the world (549 in 1920) other sections, Puu Kea, had only 7.9 inches in the same year. These conditions also afford wonderful ecological opportunities. Sharp localization of flora is found on the two sides of a mountain or the opposite sides of a valley or on the lava flow of 1841 or of 1881 as it stretches through both wet and dry regions.

The flora of the island is highly endemic. Hillebrand states that excluding the species introduced by man there are 860 species of which 653 or 76% are endemic with 40 endemic or peculiar genera, figures which are approximately true in the light of present knowledge. Many wonderful and interesting forms occur, e. g., the Silver sword and Gunnera.

It is, however, the fungi in which I am particularly interested. Less than 130 species, aside from those of economic crops had been identified as occurring in the Hawaiian Islands prior to my collections of the summer of 1921, and very few of these had been recorded by publication. My own collections number something over 1,200 and represent trips into all types of floras. Examination of some of these has been completed and the results are being published by the Bishop Museum, others are being studied.

The genus Meliola and its near relatives is represented by 34 species on 58 hosts (4 on 4 hosts were previously known). Porto Rico gave 103. The ratio to available host species in Hawaii is .034 as against .046 in Porto Rico, a very significant difference showing the Meliolas to be approximately 50% more abundant in Porto Rico than in Insular Hawaii. The Meliolas are strictly limited to the ancient flora of the island and show decided evidence of western origin being much more closely related to the Polynesian flora than to that of South America. This is particularly emphasized by the genus Meliolina, typically Philippine.

Transition genera between families are also of especial interest. Thus the genera Meliola, Amazonia, Actimodothis present a series connecting the Microthyriaceae with the Dothideales and I believe that there is evidence from those studies that the present group of Dothideales is of polyphyletic origin. An interesting case of evolution occurs on Perrottetia in that there are both a well defined Amazonia and an Actinodothis on this host, clearly related as is shown by the hyphopodia and spores but now well differentiated into two genera, an evolution that evidently occurred from an ancestral form while on this host.

The rusts now number 38 on 44 hosts, fourteen are additions to the Hawaiian flora.

In Hawaii there are 38 rusts on 999 potential hosts.

In Porto Rico there are 175 rusts on 2,250 potential hosts.

In Indiana there are 172 rusts on 2,339 potential hosts.

The rust ratio of Hawaii thus is .038 as against .77 for Porto Rico and 0.73 for Indiana. The close agreement between the ratios of Indiana and Porto Rico is striking, while the low ratio of Hawaii shows rusts there to be approximately half as common as in Porto Rico. The absence of aecial forms is also striking; only one, an imported form, was found. As to their continental relationship it appears that six came from America, one only from the West and three others may have come from either stae

or west. Contrary then to the Meliolas the rusts appear to have been dominated by the east. Most of the rusts are clearly imported and of very recent existence upon the islands.

The six rusts on endemic hosts too are of very unusual character consisting of isolated sori and not a general leaf infection such as is usual with other rusts. This condition suggests to me the possibility that these rusts are all as yet ill-adapted to their hosts. All of the evidence appears to show the rust flora to be recent as compared with the Meliola flora.

The Trichopeltaceae are particularly interesting morphologically, presenting a type of thallus unique in the fungi and in general resembling that of the liverworts. My collections in this group are larger than ever before made and result in several new genera and some modifications in classifications previously used. The genera Trichopeltis, Trichothallus, Enthallopycnidium and Anomothallus are of especial interest.

Microthyriella hibisci is of interest as throwing light on the possible relationship of the apple fly speck fungus.

Hexagonella is a remarkable form with solitary naked asci in a thallus of the type of the Hemisphaeriales.

The Dothideales which are very numerous in Porto Rico are very few in number. The genus Phyllachora so common here and in most places is represented by only two species, one possibly an import. The few Dothids that were collected are noteworthy. Yoshingiella shows a remarkable evolution on the tree fern Cibotiom it having evidently developed from a common ancestor while on this host into three distinct forms.

Pauahia, a genus which I have named in honor of the Princess Bernice Pauahia who did so much for science in the Pacific, is a very interesting transition form midway between the superficial radiate Microthyriaceae and the subcuticular non-radiate Dothids.

The smuts are conspicuous by their absence; only one really native one was found and its birthplace is questionable though smuts elsewhere are so common.

I have not time to discuss other groups, much though I would like to do so. It is evident I think that the questions in Phylogemy and geographic distribution that arise in the Pacific are of keen interest and that more complete knowledge of the insular fungus floras and of those of the east and west lands is needed.

THE CONVENTIONAL EXAMINATION IN CHEMISTRY AND PHYSICS VERSUS THE NEW TYPES OF TESTS. PART III.[1]

An Analysis of the College Entrance Board Examinations in Physics

BY EARL R. GLENN,

The Lincoln School of Teachers College, Columbia University, New York, and Ivan L. Brookmeyer, Chestnut Hill Academy, Chestnut Hill, Philadelphia.

Section 1. A Statement of the Physics Topics Found in the Examinations with the Frequency of Occurrence for Each Topic.

Section 2. A Discussion of the Data Revealed by the Analysis.

OUTLINE FOR SECTION 1.

I. Introduction.
II. Methods used in the investigation.
III. Sources of error in the analysis.
IV. Old plan questions 1911-1922.
   1. Total number of items of information asked for 1911-1922.
   2. Questions and parts of questions distributed by mechanics, heat, electricity, sound, and light.
   3. Questions and parts of questions distributed by definitions of physical terms, laws, physical phenomena to be explained, problems, and experiments.
   4. Distribution of subject matter of mechanics.
   5. Distribution of subject matter of heat.
   6. Distribution of subject matter of electricity.
   7. Distribution of subject matter of sound.
   8. Distribution of subject matter of light.
V. Comprehensive questions 1916-1922.
VI. The characteristics of an ideal test.

I—INTRODUCTION.

In the attempt to find the best selection of subject matter for the physics course of the modern high school, it is important that we survey all the opinions that are now available. The subject matter of the College Entrance Examination Board questions in physics is of great importance in this connection, not because of the high percentage of high school pupils taking these examinations, but because of the influence of these set examinations upon teachers, authors, and publishers of text books. We have thought it wise to classify the subject matter of these examinations that have been given during the past ten or twelve years in order to discover what this Board regards as of chief importance in the high school physics course. This classification should be especially useful to those teachers of physics, who feel the need of adapting the course to wider interests and purposes, while being required to prepare a few pupils for these examinations.

[1]Glenn, Earl R. "The Conventional Examination in Chemistry and Physics Versus the New Types of Tests, Part I." School Science and Mathematics, *21*. 644-647. Part II, *21*. 746-757.

II—Methods Used in the Investigation.

In the classification of the subject matter of these examinations, we first wrote each question upon a card. Then each question was carefully analyzed in order to find what facts or laws of physics were required for the correct answer to the question. Each definition, law or fact, physical phenomenon, formula or experiment required in the correct answer to the question was broken up into separate scientific items. As a result of this analysis, the fifteen questions commonly given on one examination were found to contain from 25 to 40 distinct items from the commonly accepted outline of high school physics. In order to visualize the distribution of this subject matter, we have prepared the tables which follow.

III—Sources of Error in the Analysis.

On several occasions we have been asked to state our opinion of the reliability of such an analysis as we have under consideration. In other words, if this study is repeated, by other individuals, will the same classification and frequencies be obtained? There is undoubtedly a certain error inherent in the methods used in this analysis, but we found that the variation in number of topics found in a given examination by two different individuals was approximately three out of a total of 35 to 40 topics appearing in a given examination. This method of checking the objectivity of the analysis was applied several times to different examinations with the result that the error amounted to approximately three points in 40. These errors were found to be due to the fact that one person used a slightly different classification from that of the other.

IV—Old Plan Questions 1911-1922.

Table I. Total number of items of information asked for 1911-1922.

Year	*Number of items*	*Approximate per cent of failures*
1911	35	46
1912	33	58
1913	33	42
1914	25	44
1915	35	41
1916	32	50
1917	33	40
1918	36	46
1919	34	41
1920	40	44
1921	31	....
1922	39	....

Table 2: Questions and parts of questions distributed by mechanics, heat, electricity, sound and light.

Division.	*Number of items.*
1. Mechanics	134
2. Heat	78
3. Electricity	68
4. Sound	59
5. Light	70
Total	409

Table 3: Questions and parts of questions distributed by definitions of terms, laws, physical phenomenon to be explained, problems, and experiments.

Division	Mechanics	Heat	Electricity	Sound	Light	Total
Physical terms	17	15	0	8	5	45
Laws and facts	52	20	4	21	6	103
Physical phenomenon	13	10	20	11	28	82
Problems	48	24	40	13	29	154
Experiments	4	9	4	6	2	25
Total	134	78	68	59	70	409

Table 4: Distribution and frequency of subject matter of mechanics

(A) *Definition of physical terms*

Appears
Appears
Appears
Appears
Appears
Appears
Appears

1. Moment of force	3	times
2. Mass	2	"
3. Density	2	"
4. Weight	2	"
5. Momentum	2	"
6. Acceleration	2	"
7. Specific gravity	1	"
8. Work	1	"
9. Power	1	"
10. Unit of force	1	"

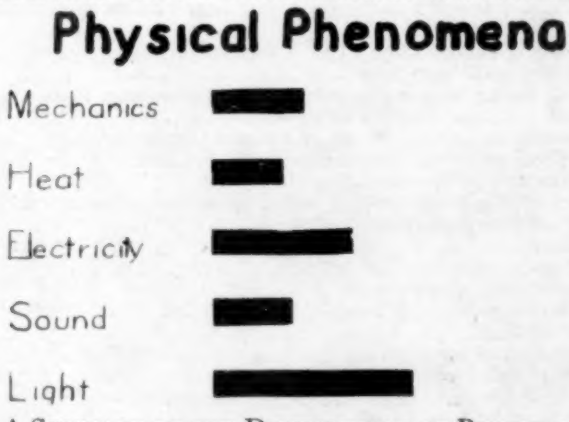


FIG. 1. A SUMMARY OF THE DISTRIBUTION OF PHYSICAL TERMS.

(b) *Laws or facts to be stated or used*

1. Work equals force times distance	7	times
2. Archimedes' principle	6	"
3. Principle of moments	6	"

4. One horse power equals 550 ft. lbs. per sec. .... 5 "
5. Meaning of center of gravity .... 4 "
6. Boyle's law .... 3 "
7. Newton's laws of motion .... 3 "
8. Component of force .... 2 "
9. Pressure in liquids ($p = h \times d$) .... 2 "
10. Parallelogram of forces .... 2 "
11. Specific gravity .... 2 "
12. Mechanical advantage of pulley system .... 2 "
13. Conservation of energy .... 1 "
14. Pascal's principle .... 1 "
15. Miscellaneous items, 6 in all, each .... 1 "

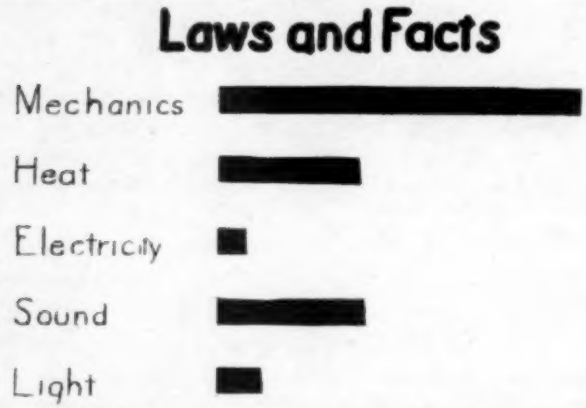


FIG. 2. A SUMMARY OF THE DISTRIBUTION OF LAWS AND FACTS TO BE STATED.

(c) *Physical phenomena to be described or explained*

1. Why does object change weight in going from equator to pole .... 2 "
2. Diagram pulley system .... 2 "
3. Description and use of hydrometer .... 1 "
4. Why easier to roll a barrel up a long board into wagon than to lift it vertically .... 1 "
5. Changes in energy when a ball is thrown vertically upward .... 1 "
6. Why do "bad" eggs sink .... 1 "
7. Use of spring and beam balance in determining mass and weight .... 1 "
8. Construction and operation of aneroid barometer .... 1 "
9. Height of aeroplane determined by barometer .... 1 "
10. Illustrations of Newton's laws of motion .... 1 "
11. Effect of angle on tension when three forces acting at a point are in equilibrium .... 1 "

(d) *Problems*

1. Efficiency equation .... 7 "
2. Equation for moments .... 5 "
3. Gas-law equation (all forms) .... 5 "
4. $D = M/V$ .... 4 "
5. Resolution of force .... 3 "
6. Work equals force times distance .... 3 "
7. $F = Axhxd$ .... 3 "
8. $S = \frac{1}{2} gt^2$ or $S = \frac{1}{2} at^2$ .... 3 "
9. $v = gt$ or $v = at$ .... 2 "
10. Work principle applied to windlass .... 2 "
11. Specific gravity using Archimede's principle .... 2 "
12. Work principle applied to inclined plane .... 2 "

13. Work principle applied to pulley system.......2 "
14. Three forces in equilibrium acting at a point.......2 "
15. K. E. = $Wv^2/2g$.......1 "
16. P. E. = Wxh.......1 "
17. Distance equals velocity times time.......1 "

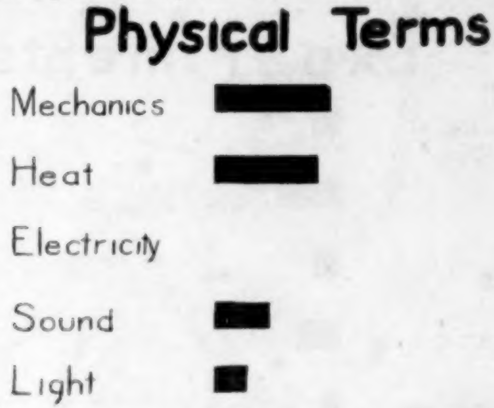


FIG. 3. A SUMMARY OF THE DISTRIBUTION OF PHYSICAL PHENOMENA TO BE DESCRIBED OR EXPLAINED.

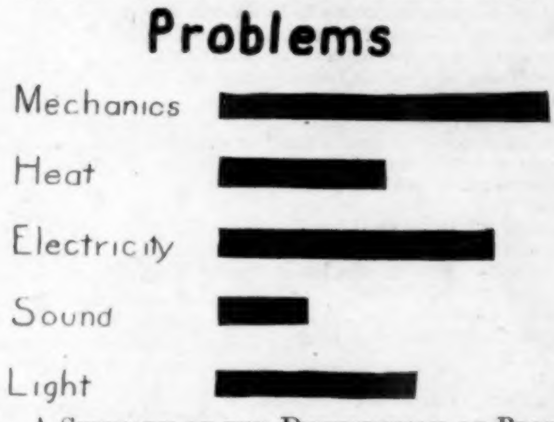


FIG. 4. A SUMMARY OF THE DISTRIBUTION OF PROBLEMS.

) *Experiments to be described.*
1. Determination of coefficient of friction.......1 time
2. Experimental proof of Archimede's principle.......1 "
3. Parallelogram of forces.......1 "
4. Boyle's Law.......1 "

(a) *Definition of physical terms.*
1. Mechanical equivalent of heat.......3 times
2. Dew point.......2 "
3. Relative humidity.......2 "
4. Specific heat.......2 "
5. Conduction.......1 "
6. Convection.......1 "
7. Radiation.......1 "
8. Temperature vs. quantity of heat.......1 "
9. Temperature.......1 "
10. Heat of fusion.......1 "

(b) *Laws or facts to be stated or used.*
1. Heat of fusion of ice .... 7 times
2. Specific heat of metal .... 6 ''
3. Heat of vaporization of water .... 5 ''
4. Mechanical equivalent of heat .... 1 ''
5. Meaning of B. T. U .... 1 ''

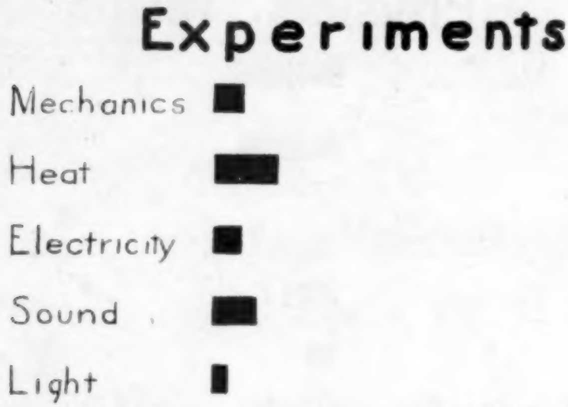


FIG. 5. A SUMMARY OF THE DISTRIBUTION OF EXPERIMENTS.

(c) *Physical phenomena or devices to be described or explained.*
1. Cooling effect of evaporation .... 3 times
2. Construction and operation of ice plant .... 1 ''
3. Temperatures of clear and cloudy nights .... 1 ''
4. Condensation from breath on cold day .... 1 ''
5. Convection in chimney .... 1 ''
6. Why a pond does not freeze solid in winter .... 1 ''
7. Methods of transferring heat and examples of each .... 1 ''
8. Three systems of heating houses .... 1 ''

(d) *Problems.*
1. Method of mixtures equation .... 7 times
2. Coefficient of linear expansion equation .... 5 ''
3. Heat units = mass $\times$ change in temp. $\times$ sp. ht .... 4 ''
4. Gas equations (all forms) .... 3 ''
5. Efficiency equation .... 2 ''
6. Mechanical equivalent of heat .... 1 ''
7. P. E. = Wxh .... 1 ''
8. K. E. = $\frac{1}{2}mv^2$ .... 1 ''

(e) *Experiments to be described.*
1. Heat is a form of energy .... 2 times
2. Low conductivity of water .... 1 ''
3. Determination of dew point .... 1 ''
4. Mechanical equivalent of heat .... 1 ''
5. Cooling curve .... 1 ''
6. Coefficient of expansion of a gas .... 1 ''
7. Relative humidity .... 1 ''
8. Specific heat .... 1 ''

Table 6: Distribution and frequency of items of subject matter in electricity.

(a) *Definition of physical terms.*
NONE

(b) *Laws or facts to be stated or used.*
1. 1 H. P. = 746 watts .... 1 time
2. Right hand rule for direction of current .... 1 ''
3. Rules for direction and magnitude of induced current .... 1 ''
4. Meaning of kilowatt-hour .... 1 ''

(c) *Physical phenomena or devices to be described or explained.*
1. Telephone transmitter .... 3 times
2. Telephone receiver .... 3 "
3. Construction and operation of transformer .... 2 "
4. Long distance transmission of electricity .... 2 "
5. Storage cell .... 1 "
6. Electroplating .... 1 "
7. Distribution of charge on insulated conductor .... 1 "
8. Effect of a charged body on a electroscope near it .... 1 "
9. Diagrams of cells in series and parallel .... 1 "
10. Effect of breaking a magnet .... 1 "
11. Diagram of house wiring for door bell .... 1 "
12. Electromagnet vs. permanent magnet .... 1 "
13. Electromagnet, construction and strength .... 1 "
14. Corrections in reading of compass in navigation .... 1 "

(d) *Problems*
1. Ohm's law (all forms) .... 11 times
2. Watts = $I \times V$ .... 5 "
3. Joint resistance of parallel circuits .... 5 "
4. Distribution of current in parallel circuits .... 4 "
5. Efficiency equation .... 4 "
6. H (calories) = $1\ 2/x\ Rxtx$ .24 .... 3 "
7. Electrochemical equivalent of metal .... 3 "
8. Joint resistance in series .... 3 "
9. Transformer equation for e. m. f. .... 1 "
10. Relation between watts and candle-power .... 1 "

(e) *Experiments to be described.*
1. Testing distribution of charge on insulated conductor .... 1 time
2. Ammeter—Voltmeter method for resistance .... 1 "
3. Induced current by moving wire in earth's magnetic field .... 1 "
4. Sign of electrification on charged body .... 1 "

Table 7: Distribution and frequency of items of subject matter in sound.

(a) *Definition of physical terms.*
1. Noise vs. musical sound .... 2 times
2. Intensity .... 2 "
3. Quality .... 2 "
4. Pitch .... 2 "

(b) *Laws or facts to be stated or used.*
1. Velocity of sound at 0°C .... 9 times
2. Velocity of sound changes 60 cm per sec 1°C .... 8 "
3. Relation between no. of beats and frequencies .... 3 "
4. Variation of intensity of sound with distance .... 1 "

(c) *Physical phenomena or devices to be described or explained.*
1. Interference of sound .... 3 times
2. Transmission of sound .... 3 "
3. Echo .... 2 "
4. Resonance .... 2 "
5. Source of sound .... 1 "

(d) *Problems.*
1. Relation of distance, speed, and time .... 5 times
2. $v = nl$ .... 4 "
3. Resonant length for closed pipe .... 2 "
4. Formula for beats .... 2 "

(e) *Experiments to be described.*
1. Pitch of musical sound .... 3 times
2. Wave-length of musical sound .... 1 "
3. Velocity of sound in open air .... 1 "
4. Width of lake using gun, stop watch, and thermometer .... 1 "

Table 8: Distribution and frequency of items of subject matter in light.

(a) *Definition of physical terms.*
1. Index of refraction .... 3 times

2. Shadow vs. image ... 1 "
3. Conjugate foci ... 1 "

(b) *Laws or facts to be stated or used.*

1. The speed of light ... 3 times
2. Images formed by lenses ... 2 "
3. Principal focus of mirror ... 1 "

(c) *Physical phenomena or devices to be described or explained.*

1. Solar spectrum ... 5 times
2. Pin-hole camera ... 2 "
3. Color of opaque objects ... 2 "
4. Color of mixture of yellow and blue pigments ... 2 "
5. Color of objects in various colors of light ... 2 "
6. Continuous spectrum ... 1 "
7. Bright line spectrum ... 1 "
8. Color of transparent objects ... 1 "
9. Explanation of refraction by wave theory ... 1 "
10. Roemer's method ... 1 "
11. Eye-glass for far-sighted eye ... 1 "
12. Refraction at edge of pond ... 1 "
13. Images of lenses of compound microscope ... 1 "
14. Critical angle for water ... 1 "
15. Matching colors in daylight and artificial light ... 1 "
16. Wave theory explanation of spectrum ... 1 "
17. Photometer ... 1 "
18. Path of light thru telescope ... 1 "
19. Images in plane, convex and concave mirrors ... 1 "
20. Index of refraction for "red light" and for "green light" ... 1 "

(d) *Problems.*

1. $1/Do+1/Di = 1/f$ ... 9 times
2. $Lo/Li = Do/Di$ ... 9 "
3. Photometer proposition ... 5 "
4. Index of refraction = V1/V2 ... 2 "
5. Radius of mirror = twice focal length ... 1 "
6. Plane mirror diagram ... 1 "
7. Magnifying power of telescope ... 1 "
8. Law of Inverse squares ... 1 "

(e) *Experiments to be described.*

1. Production of spectrum of luminous body ... 1 time
2. Index of refraction for glass ... 1 "

V—Comprehensive Plan Questions 1916-1922

Table 1: Total number of items of information asked for 1916-1922.

Year	*Number of items.*
1916	42
1917	47
1918	51
1919	40
1920	36
1921	33
1922	38

Table 2: Questions and parts of questions distributed by mechanics, heat, electricity, sound and light.

Division	*Number of items.*
1. Mechanics	88
2. Heat	56
3. Electricity	58
4. Sound	33
5. Light	52
Total	287

Table 3: Questions and parts of questions distributed by definitions of terms, laws, physical phenomena to be explained, problems and experiments.

Division	*Mechanics*	*Heat*	*Electricity*	*Sound*	*Light*	*Total*
Physical Terms	9	8	0	5	8	30
Laws and facts	19	16	5	9	11	60
Physical Phenomena	10	10	22	6	14	62
Problems	48	19	29	10	18	124
Experiments	2	3	2	3	1	11
Total	88	56	58	33	52	287

Table 4: Distribution and frequency of subject matter of mechanics.

(a) *Definition of physical terms.*

1. Mechanical advantage .... 2 times
2. Work .... 2 "
3. Potential energy .... 1 "
4. Kinetic energy .... 1 "
5. Coefficient of friction .... 1 "
6. Horse power .... 1 "
7. Efficiency of a machine .... 1 "

(b) *Laws or facts to be stated or used*

1. Archimedes' Principle .... 7 times
2. 1 H. P. = 550 ft. lbs. per sec .... 2 "
3. Meaning of center of gravity .... 2 "
4. Principle of Conservation of Energy .... 1 "
5. Weight of 1 cu. ft. of water .... 1 "
6. Action of compression air pump .... 1 "
7. Height of mercury in barometer independent of diameter .... 1 "
8. Meaning of frictional resistance .... 1 "
9. Uniformly accelerated and uniformly retarded motion .... 1 "
10. Newton's Laws of Motion .... 1 "
11. Boyle's Law .... 1 "

(c) *Physical Phenomena to be described or explained.*

1. Drawing of pulley systems .... 2 times
2. Transformation of energy in falling body .... 1 "
3. Mercury barometer .... 1 "
4. Lifting stone under water .... 1 "
5. Surface tension .... 1 "
6. Archimedes' principle in aeronautics .... 1 "
7. Why a stone can be thrown further than a cork .... 1 "
8. Illustrations of Newton's laws of motion .... 1 "
9. Effect of angle on tension in ropes .... 1 "

(d) *Problems.*

1. K. E. = $Mv^2/2g$ .... 4 times
2. $F = A \times h \times d$ and $p = h \times d$ .... 4 "
3. D = M/V .... 4 "
4. Efficiency formula .... 4 "
5. Work = F×S .... 3 "
6. $F \times t = Mv/g$ (momentum) .... 3 "
7. Boyle's Law .... 3 "
8. Inclined plane, $W \times h = F \times l$ .... 2 "
9. Coefficient of friction = force of friction/weight .... 2 "
10. S = 1/2 at 2 or $S = 1/2\ gt^2$ .... 2 "
11. Power = Work/(550 ft. lbs. per sec.) .... 2 "
12. Equation for moments .... 2 "
13. Distance = average velocity × time .... 2 "
14. Three forces in equilibrium acting at a point .... 2 "
15. P. E. = $W \times h$ .... 1 "
16. $v = at$ .... 1 "
17. Equality of sums of 11 forces in opposite directions .... 1 "
18. Work principle applied to capstan .... 1 "
19. Work principle applied to jackscrew .... 1 "
20. Acceleration = (gain in velocity)/time .... 1 "
21. $F = m \times a$ .... 1 "
22. $v^2 = 2\ gS$ .... 1 "

23. sp. gr. = (weight of body in air)/(loss of weight in water)..1 time

(e) *Experiments to be described.*

1. U-tube method of measuring gas pressure .... 1 time
2. Boyle's Law experiment .... 1 "

Table 5: Distribution and frequency of subject matter of heat.

(a) *Definition of physical terms.*

1. Coefficiency of expansion .... 2 times
2. Mechanical equivalent of heat .... 2 "
3. Unit quantity of heat .... 1 "
4. Temperature .... 1 "
5. Specific heat .... 1 "
6. Heat of fusion .... 1 "

(b) *Laws or facts to be stated or used.*

1. Specific heat .... 7 times
2. Latent heat of condensation and vaporization .... 5 "
3. Latent heat of melting .... 2 "
4. Mechanical equivalent of heat .... 1 "
5. Transferring heat from steam in radiator to room .... 1 "

(c) *Physical phenomena to be described or explained.*

1. Cause of ice melting in closed refrigerator .... 1 "
2. Comparison of mercury and air thermometer .... 1 "
3. Pans of water in greenhouse to prevent freezing .... 1 "
4. Effect of sprinkling street on hot day .... 1 "
5. Hot days more unpleasant in moist than dry climate .... 1 "
6. Apparatus for distillation of water .... 1 "
7. Reciprocating steam engine .... 1 "
8. Four cycle gas engine, construction, operation, cooling system .... 1 "
9. Example of cooling effect of evaporation .... 1 "
10. Three systems for heating houses .... 1 "

(d) *Problems.*

1. Heat units = mass × change in temp. × sp. ht .... 7 "
2. Mixture equation .... 4 "
3. Gas equations (all forms) .... 3 "
4. P. E. = $M \times h$ .... 2 "
5. Efficiency equation .... 1 "
6. Relation of F and C temperatures .... 1 "
7. $e = kl\ (t-t)$ .... 1 "

(e) *Experiments to be described.*

1. Coefficient of expansion .... 2 "
2. Latent heat of vaporization .... 1 "

Table 5: Distribution and frequency of subject matter of electricity.

(a) *Definition of physical terms.*

NONE

(b) *Laws or facts to be stated or used.*

1. Meaning of kilowatt-hour .... 2 times
2. Name of discoverer of induced currents .... 1 "
3. Lenz's Law .... 1 "
4. Heat losses in transmission of electricity .... 1 "

(c) *Physical phenomena or devices to be described or explained.*

1. Telephone receiver .... 2 times
2. Galvanometer or ammeter .... 1 "
3. Commercial transformer .... 1 "
4. Long distance transmission of electricity .... 1 "
5. Leaf electroscope .... 1 "
6. Charging electroscope by induction .... 1 "
7. Use of electroscope in detecting positive charge .... 1 "
8. Electricity produced by chemical action .... 1 "
9. Two machines depending on induction .... 1 "
10. Relative importance of two methods of producing currents 1 "
11. Type of cell for ringing bells .... 1 "
12. Local action in voltaic bell .... 1 "

13. Polarization of cells....1 time
14. Use of ammeter....1 "
15. Use of voltmeter....1 "
16. Electric bell....1 "
17. Telegraph key and sounder....1 "
18. Alternating current generator....1 "
19. Transformation of energy in generator....1 "
20. Drawing of electric circuit....1 "
21. Telephone transmitter....1 "

(d) *Problems.*

1. Watts = volts×amperes....8 times
2. Ohm's Law (all forms)....7 "
3. Distribution of current in parallel and series circuits....5 "
4. Resistances in series and parallel....4 "
5. H (calories) = $I^2 \times R \times t \times .24$....2 "
6. Voltage formula for transformer....1 "
7. Watts = $I^2 \times R$....1 "
8. Efficiency equation....1 "

(e) *Experiments to be described.*

1. Determination of resistance of wire....1 time
2. Voltmeter-ammeter method of measuring resistance....1 "

Table 6: Distribution and frequency of subject matter of sound

(a) *Definition of physical terms.*

1. Pitch....1 time
2. Quality....1 "
3. Frequency....1 "
4. Resonance....1 "
5. Forced vibrations....1 "

(b) *Laws or facts to be stated or used.*

1. Laws of vibrating strings....1 time
2. Frequency and pitch....3 "
3. Compare speeds of light and sound....1 "
4. Amplitude of vibration and loudness....1 "
5. Velocity of sound at 0°C....1 "
6. Effect of temperature on velocity....1 "
7. Characteristics of musical sounds....1 "

(c) *Physical phenomena or devices to be described or explained*

1. Echo....2 times
2. Noise vs. musical sound....1 "
3. Compare notes by violin and cornet....1 "
4. Formation of beats....1 "
5. Resonance....1 "

(d) *Problems.*

1. $v = nl$....3 times
2. Formula for beats....2 "
3. Closed organ pipe = $\frac{1}{4} l$....2 "
4. Open organ pipe = $\frac{1}{2} l$....2 "
5. Laws of vibrating strings....1 "

(e) *Experiments to be described.*

1. Rate of vibration of sounding body....1 time
2. Determining velocity of sound in air....1 "
3. Relation between pitch and frequency....1 "

Table 7: Distribution and frequency of subject matter of light.

(a) *Definition of physical terms.*

1. Index of refraction....3 times
2. Candle power....1 "
3. Spectrum....1 "
4. Principal focus....1 "
5. Conjugate foci....1 "
6. Refraction....1 "
7. Critical angle....1 "
8. Reflection....1 "
9. Dispersion....1 "

(b) *Laws or facts to be stated or used.*
1. Images formed by concave mirror....2 "
2. Images formed by plane mirror....2 "
3. Index of refraction....1 "
4. Explanation of refraction....1 "
5. Explanation of dispersion....1 "
6. Images formed by convex mirror....1 "
7. Compare images formed by thin and thick lenses....1 "
8. Images formed by lenses....1 "
9. Compare index of refraction for "red light" and for "green light"....1 "

(c) *Physical phenomena or devices to be described or explained*
1. Formation of spectrum....3 "
2. Drawing of images in concave mirrors....1 "
3. Drawing of path of light thru water and glass obliquely and perpendicularly....1 "
4. Meaning of Fraunhofer lines....1 "
5. Colored objects in colored lights....1 "
6. Shadows cast by arc lamp and gas jet....1 "
7. Draw of path of light obliquely from air into water....1 "
8. Color of colored objects in natural and artificial lights....1 "
9. Drawing of images in microscope....1 "
10. Drawing of images in telescope....1 "
11. Physical difference between "red light" and "blue light"....1 "
12. Drawing of lenses and images in stereopticon....1 "

(d) *Problems.*
1. Law of Inverse Squares....4 times
2. Bunsen photometer proportion....4 "
3. $l/Do + l/Di = l/f$....4 "
4. $Lo/Li = Do/Di$....4 "
5. Time of exposure and intensity of illumination....2 "
6. Use of similar triangles in image diagrams....1 "

(e) *Experiments to be described.*
1. Measuring intensity of light....1 "

VI.—Conclusions.

Upon another occasion we expect to compare the distribution of subject matter as shown by this study with the contents of a typical physics text book. At that time we shall submit data showing the per cent of high school students in the country, as a whole, who take these examinations, and we hope also to discuss certain statistical errors that are associated with this type of examination.

From our point of view several important questions should be considered in discussing the value of any test or examination.

(a) Sample—Is the test known to be random sample of the subject with respect to difficulty and number of questions?

(b) Validity—Does the test measure certain types of performances in physics which are known to be essential in this science?

(c) Objectivity—Will different examiners assign similar scores to the same student? Are the pupils' answers of such a character that the same score will be assigned by different teachers?

(d) Range of abilities—Is the test known to differentiate between dull, average and superior pupils?

(e) Standard scores—Have the average scores been determined upon a sufficiently large number of cases?

(f) Reaction of students—Do pupils enjoy the test and exert their maximum effort?

(To be continued.)

THE PROJECT METHOD IN SECOND SEMESTER HIGH SCHOOL CHEMISTRY.

By Frank B. Wade,

Shortridge High School, Indianapolis, Ind.

So many requests have come to the chemistry editor for information as to how to proceed in using the project method in chemistry that the following letter to one such correspondent is printed below in the hope that it may be of use to others.

My dear Mr. ———:

Your request for references in regard to the project method in chemistry was forwarded to me as Editor for Chemistry of School Science. I am sorry that I cannot refer you to definite references. There has been quite a bit printed in regard to project material in General Science but very little so far as I know in Chemistry.

In my own department, we have been using the project method for some years, during the latter part of the second semester. Miss Ellinor Garber, one of my teachers, became interested in it during a year spent at Columbia University several years ago and took the course in the project method in General Science so as to be able to apply the findings in that subject to a similar course in chemistry. On her return she tried her ideas out on one class of second semester pupils and at the same time I tried the method on one of my classes. I liked the results so well that we have extended the work so that all of my teachers do more or less project work in the second semester, some of them for only a month or six weeks and others longer. Last semester I started my group in October and carried them through January in purely project work. In November 1921 Miss Garber read a paper at St. Louis before the Central Association of Science and Mathematics teachers on her experiment with the project method and that paper was published in School Science in March, 1922. You can run that down in the files of School Science and Mathematics.

Miss Garber gave some tentative lists of projects in that paper.

If it will help you I will append a brief outline of my last years projects.

List of Chemistry Projects used last year at Shortridge High School, Indianapolis, Ind.:

The first group of projects was limited to those concerned with compounds of sodium and related topics. Committees of from

two to four pupils were allowed to draw lots and select projects from among the following themes:

1. How do they make baking powders? (Two girls took this—they used the reference library—got types of baking powders—learned equations—(had to study up ionic theory here) learned hydrolysis and taught it to the class in connection with alum in baking powders.) Outline (a) history—(b) chemistry—(c) manufacture—(d) laboratory preparation. They made some baking powder and made and frosted a cake, using their own baking powder, and treated the class when they gave their report. (These little things help interest the committee and the class and fix things in their memories.) The class stopped all laboratory work on the appointed day and the committee reported, the class asked questions; the committee dictated questions on essentials of the project to the class. I keep a copy of these questions and when the class is examined I give both "major" and "minor" tests. Each committee gets, say five, questions from me on its own project, and two or three questions chosen from those dictated by the committees on every project. This scheme helps to fix the subject matter of the other fellow's report. Pupils of course never know the other material as well as they know their own projects, but the use of Powers' tests on project vs non-project sections seems to show that the project classes know *all the ground we cover*—at least as well as the other classes and much of it they know very much more intimately than the others.

(2) Fire extinguishers and how they work. (Two girls worked this up. One was the daughter of a fireman in the city department.) This project of course centered around $NaHCO_3$—it brought in ionization again, so the class got a second lesson on that. Hydrolysis came in again in connection with the Foamite Fire Extinguisher which uses Aluminum Sulphate as its source of acid by hydrolysis with water. One of the girls got the state agent of the Foamite extinguisher interested (on her own initiative) and brought him up to school to stage a specimen fire on the day she made her report. She had a boy use one of the school extinguishers (Babcock type) on several gallons of gasoline, floated on half a tub full of water. Of course it was futile. Then she put another boy to work with a carbon tetrachloride extinguisher, without success. Then the Foamite man put out the fire with about one half of his three gallon extinguisher. The girls explained the chemistry and the mechanism of the various types of extinguishers. I have gone into detail on one or

two projects to give you an idea how we go about them. We are exploring so to speak and have to feel our way in these new methods.

(3) How is the baking soda used in No. 1 and No. 2 made? (Pupils look up history of the alkali industry—learn of the early methods, the more recent LeBlanc method and the modern Solvay process, carry on the latter on a small scale—again use ionic equations, discuss conditions promoting yield, describe manufacture on large scale etc.)

(4) Soda Ash and Sal Soda. Make the Na_2CO_3 from $2NaHCO_3 \longrightarrow$ Weigh both and check up on equation. Hydrate Na_2CO_3 Roughly quantitative. Accurate quantitative efflorescence and calculation of xH_2O in residue from $Na_2CO_3, 10H_2O \longrightarrow xH_2OI + Na_2CO_3, 10\text{-}x\ H_2O$.

(5) How is lye made nowadays? Committee of two. Look up old methods. (a) Use caustisization of Na_2CO_3 with $Ca(OH)_2$. (b) Also use electrolysis of brine. Discuss concentrations and solubilities in (a) Teach electrolysis in (B). Describe and draw diagrams of Castner-Kellner and other recent processes.

(6) Chile Saltpeter, gunpowder, fertilizer, nitric acid and modern high explosives. I had four boys on this. They had our Senior military companies up the day they reported. One boy made black gunpowder—granulated and graded it—loaded a 32 Caliber shell and fired it from a revolver at a pack of paper towels backed by a cast iron back ground. Another boy made gun cotton, dissolved it, made smokeless powder and granulated it. Various colored fires were also made and sodium, strontium, and barium flame color and spectra were taught by one boy. The geologic occurrence-geography, political relations between Chile and Peru on account of the nitrate beds, and the fertilizer value were treated by another boy. In some years I have had a boy on artificial fixation of nitrogen in connection with this project. If any pupil sees a lead that promises some effective work I let him go at it.

After the above first round of projects I have usually taken up the calcium compounds and built projects such as:

(1) How is lime made? (Mortar and plaster and white wash came in here). Quick lime and hydrated lime.

(2) Limestone caves—stalactites and stalagmites. We have many caves in Southern Indiana.

(3) Hard water—its causes, effects and remedies. Committee visits laundries—factories, etc., in school time. For an actual

report by a boy on one phase of this project see School Science and Mathematics—I think in the November number, 1922. One of my boys without any knowledge of the Permutite process for artificially producing a zeolite—worked up a method, made his own zeolite and softened water with it. I published his report as a sample of what can be done in project work.

(4) Plaster of Paris—(Portland Cement can be studied by same committee).

After two rounds of limited projects such as the above, I usually give the pupils more rein. I suggest various interesting things and also let them suggest projects. Some of the fields covered last semester were:

(1) Making Karo from corn starch (The committee used a pressure cooker in hydrolyzing the starch and evaporated the sirup in the same cooker with an aspirator producing a partial vacuum. Fehling's test, and the iodine starch test were reported on and used by the committee. They taught the class a little organic chemistry.

(2) Another committee inverted sucrose, made fondant and treated the class. Taught mono and poly saccharoses, etc.

(3) Two girls made a splendid pure white soap—scented it—cut it and gave a small cake to each member of the class, taught fatty acids and repeated hydrolysis.

(4) Two boys got some crude petroleum, ran a fractional distillation getting a "straight run" gasoline and taught marsh gas series—also described casing—head blend and cracked gasoline.

(5) Two boys ran an assay of a gold-silver ore.

(6) Two boys recovered twenty-five grams of gold and palladium—without loss—for a chemist whose apprentice had put a "palau" crucible into aqua-regia.

(7) Two boys ran a flash and fire test of an oil for the underwriters inspection bureau here.

(8) Two girls made a study of the production of artificial gems and actually made some artificial minerals by using boric acid solutions of silicia and alumina, borrowing the use of the U. S. Encaustic Tile Company's Kilns.

(9) One boy worked up the chemistry of photography—made blue-print paper, etc. Visits to public library or commercial plants are allowed in school time, when our eighty-minute period permits.

(10) Two boys worked up reactions of Ag^{+}, Pf^{++}, and Hg^{+}

and worked out their own scheme of separations. Tested unknown (a counterfeit half dollar) and reported to class.

(11) One boy got equivalents of Na, Zn, and Al and used the experiment shown in W. A. Noye's text in which weights of the metals proportional to gram atomic weights are used and volumes of H_2 came out 1, 2 and 3 respectively.

(12) Glass making. Committee of three made glass (lead glass type) gave historical account. One boy treated color in glass and used borax glass to illustrate. Committee took the class to a local glass factory to see process in operation. This had to be an afternoon excursion.

(13) Metallurgy of iron and steel—demonstration of hardening and tempering tool steel. Not having any producing plants locally the blast furnace, Bessemer and Open hearth processes, were explained and black board diagrams used.

(14) Metallurgy of copper and lead. Blow pipe reduction of lead and reduction of copper oxide by hydrogen as experiments. Description of industrial methods.

This type of work is a three ring circus for the teacher. It calls for a lot of work and considerable apparatus is needed; yet much can be improvised. A Mékér burner and a sheet of asbestos make a glass furnace if a highly fusible mix is employed. A Borax admixture helps. The game is worth all the work it costs. Pupils pitch in and work and that is what counts. I used to be afraid we would not cover certain essential matter or that it would not be well covered. Mistakes made by pupils in reporting used to worry me, but I have learned to "sit tight" and not interrupt very much but to correct errors later. Fine practice in public speaking is had by the pupils when they report. I try to coach them a little in that sort of thing, too. The method begets intimate acquaintance with the members of the class. It calls for a small section, if possible, but I have been using it with from twenty-two to twenty-four in a section. Much of my experience with it has been in a selected group of brighter pupils but both I and other teachers in the department have used it with ordinary pupils. More time is lost by the latter while waiting to get assistance or suggestions from the instructor however. It is well to hold a conference with each committee a day or two before they report as so to suggest improvements, additions, omissions, etc.

Considerable steering is necessary in order to divide the available time economically between reports and active work on

projects. It is unwise to have reports too consecutively. In the early part of the work some artificial arrangement of the order in which reports are presented may be desirable so as to get first things first, as, for example, if the Solvay process report can precede the baking powder report we have a more *systematic* order, but, on the other hand, the baking powder report gives a *natural* demand for the Solvay report, so one need not worry when the usual order of a text book is violated.

WHAT THE PUPILS WANT IN THE FIRST YEAR SCIENCE CLASS[1]

By Ernest B. Collette,
Lake View High School, Chicago.

There are a few comments relating to the teacher, the pupils would like to make about things that go on in the class room.

Pupils want the teacher to be and act like common human folks and not use so many big words.

They don't want the teacher to practice on them with a lot of technical college ideas that they can neither grasp nor get interested in.

They want to remind the teacher that it is pupils he is teaching and not subjects.

They wish the teacher could appreciate how they think, and what things they understand. Too many of the things taught are of interest only to a mature mind.

They wish the teacher could understand that if they are not interested in the work, usually it is the teacher's fault; another teacher might take the same topic and have them happy, interested and eager to take part.

They want the teacher to take a little more time and not go over things so fast, if they are worth while, and give them a chance to think. Most of the questions a teacher asks are put in a way that is new to them and they don't have answers already formulated in their minds even if they do understand what it is all about.

They think it would be great sport to answer questions the teacher asked when he honestly wanted to find out something. For example, a teacher once asked the pupils how to cook mushrooms, and admitted he didn't know how; and what a storm of answers the question brought forth. He almost needed a rope to keep the pupils from crowding around his desk to tell him all about it.

[1]Read before the General Science Section of the C. A. S. & M. T. at Hyde Park High School, Chicago, December 1, 1922.

They think it takes all the pleasure out of recitations to be asked questions when they know the teacher knows the answers and is only waiting to criticize the words they use and the ideas they have. You remember one day Min was scolding Chester when he came home with face and hands all covered with dirt. She said: "What would you say if I came home with hands like those and you saw me?" Chester frankly replied: "I wouldn't say anything—I'd be too polite."

They think the average teacher is still barbaric in his attitude toward pupils, possesses immeasurable vanity, and frequently ignores and frowns down upon the pupils' complaints and ideas.

The teacher is supposed to be interested in developing personality. Personality is developed from within. He wants these pupils to react on their environment. He wants them to become first rate master-pieces. But if the teacher seeks a subservient attitude, if he seeks to have the "obedient" or "anxious to please" pupils, the weaker willed ones will adapt themselves comfortably to his dictates. Those of stronger wills will rebel, but in so far as such teaching is successful, and the subservient attitude does predominate, he has in result only second rate copies, when he might have had first rate masterpieces.

Yes, pupils think the teacher fears the foot-fall of the younger generation and instinctively desires to retain power by holding them in check.

The pupils want a chance to understand the Scientific Method. They want a chance to understand how it is different from other methods with which they have had experience. It could be explained clearly in the class-room and compared with other methods of getting knowledge. All through their lives they have been handed ideas, and in a good many cases, have never dared to draw, or even thought of drawing, their own conclusions from facts presented. If there is a correct way to reach conclusions they want to have experience to try it out, see that it works, and learn to believe in it. And you may be sure they are going to watch the teacher to see if he believes in the Scientific Method and practices it in his thinking. Take a homely example for illustration: They have been taught ever since they can remember, to "swat the fly." In the science class they get the idea of the fly's life history, and with a little guidance from the scientific teacher, they may quickly grasp the idea of how screens

on our houses, fly swatting campaigns, and even interest in the great varieties of fly traps and fly papers, are so ridiculous as compared with the careful control of breeding places in the community.

Pupils sometimes wonder about things a great deal more than we teachers realize. They have wondered, lots of times, about what education really is, and what it is for. Usually we have not made it very clear to them.

Under the name of education they have been disciplined, which is not education at all, but simply a form of guardianship. They have been told to do this and not to do that. Sometimes they have been told why certain things are good for them, and why certain things are injurious. But usually this guardianship has had but little to do with their welfare or rights. They have been guarded, too frequently, with standards of old worn out customs, which result in less irritation and inconvenience to adults, rather than the best interests of growing boys and girls. If they respond meekly, have pleasing dispositions and manners, they are likely to be petted and spoiled, become followers and learn to practice dishonorable submission to the authority of another instead of self-reliance. When some are more independent and less tactful, they are more likely to be tormented, given less consideration and lower marks, and because they seek the right to decide things for themselves they frequently become evasive, cowardly and deceitful.

Under the name of education, they have been trained, which again contains very little education; trained to travel beaten paths because others have traveled them. A teacher has called one training good and another bad, very frequently with no consideration at all as to the real welfare of the children. The teacher has handled them in "job lots," imagining that a well trained class shows signs of education when, in reality, it frequently shows education is becoming more and more impossible. How true the statement, "We are a mass of people living in a submissive routine to which we have been drilled from our childhood."

And it is no wonder pupils want to know what education is, and what it is for. They don't get it in guardianship, good or bad though that may be. They don't get it in correct or incorrect training. If they ever deserve to get it, and if there is the slightest chance of their ever getting it, it is in the Science class. They really want, and they deserve to get, a chance to think.

These pupils want to be freed from the insidious ghost fear. Even in our "enlightened" age, a teacher frequently trains pupils to be afraid. He who instills into the heart of a pupil the fear of being scolded, fear of ridicule, fear of shaming before a class, fear of low marks, fear of failure to pass, fear of making mistakes, is inevitably blocking the possibility of real education.

There is no education without freedom from haunting fear. As soon as we draw the line as to what pupils should think we make it impossible for them to think at all. The teacher who educates is never anxious about what pupils think. To be uneasy is the sign of a teacher's aim at training. It is the science teacher's privilege to see that pupils get hold, and learn how to get hold, of scientific facts. What the pupils do with these facts is the process of education; and at such a time these growing minds must be free from fear, for the human mind is so constructed that fear is the greatest enemy of thought.

Why should we be uneasy, or even particular, about what conclusions pupils draw from well organized scientific facts presented? Are we afraid of the unbeaten paths? Does the spirit of science tell us that pupils are not to explore or investigate the new roads ahead? It does not. Does it say the conclusions of the youth must be the same as ours have been? It does not. Are we teachers really scientific in our thought when we fear or hesitate to draw scientific conclusions different from old customs, habits and creeds of days gone by and of an age that is dead? Are we young enough in our thought to be leaders of the youth who are to live in the coming days of change and progress? Are we really seeking to educate pupils in our science classes, or do we want to produce a certain type of character to serve subsequent ends? A real science teacher is not afraid of, but is happy over, the newness of thought of the growing generation.

The pupils want to be freed from superstition. They are living in a day when science is coming into possession of its own. Many old superstitions, customs and beliefs are being cast into the discard of forgotten things. These pupils realize that many things are out of date, but quite generally they lack the scientific background of why newer customs and ideas are more accurate and true. It may be a science teacher is more superstitious than the pupils. He may have the superstitious idea that we are to follow leaders; be dictated to by others rather than to be thinkers and builders for ourselves; that ideas handed

down from generation to generation—unscientific as they may be—are to be believed; that statements in print must be true, even if coming from most widely circulated newspapers; that social and political standards are correct simply because they have been in practice; that men of leisure and culture are to be respected and looked up to, rather than those of the labor world who bear the burdens and run the risks of life. The teacher may lift a heavy burden from the shoulders of our youth by knowing scientific facts that relate to life, helping pupils to get a foundation, during these changing days, that will permit them to understand the kind of a civilization that man has built and how, most effectively, our younger folks may stand constructively for truth and justice in a more scientific civilization than the past has been. They need our help in hammering down the walls of superstition and ignorance. It is the old struggle of light against darkness; knowledge against ignorance; truth against superstition; freedom against fear.

The pupils want a chance to understand the perplexities of life. The day has come when further suppression of economic knowledge is most disastrous to human welfare. The pupils of our schools are quite commonly taught errors and kept in ignorance about the simplest economic facts. Yet that nation is most fortunate whose youth is taught truth—vital truth—applying to life and the happiness of mankind.

For example: Pupils very easily grasp the scientific laws about tuberculosis. They can readily understand this disease alone costs the people of our nation about one billion dollars a year, and that by following a scientific program it can be eradicated instead of having most of our attention given to curing cases, when the cause of the disease is so largely neglected as unimportant.

Another example: They learn about the wonderful scientific development of the dairy breeds of cattle, the egg producing wonders among chickens, the endless varieties of marvelous fruits and flowers, and these pupils in the public schools also know something about the thousands of babies and school children who sicken and die from insufficient nourishment, having had but little opportunity to ever appreciate the beauties of the flowers. These pupils wonder why, in a nation of plenty and scientific progress, we must have these unnecessary deaths and the flowers kept from those who would appreciate them the most.

Again, they study about the power of nature man has scientifically harnessed, the machines and inventions developed by which the work of the world is being done, intended to relieve mankind from monotonous drudgery and slavery, but in every industrial center they know something of the bitter struggle between the masters of industry and the wage workers over the length of the working day and rights of individuals. These pupils know something is wrong when a new machine is put into use, and instead of lightening men's burdens, has the effect of throwing more men into the unemployed group, which already numbers millions in the United States alone, a disastrous situation which is receiving but little serious consideration.

Pupils should have opportunity to appreciate the dignity of work—work that is valuable to themselves and the community. They see life with unemployment, starvation and monotonous drudgery, and mangled with scientific warfare, instead of its becoming more happy and free and filled with opportunity for creative work. They wonder why these marvels of science do not apply much more to life. The teacher must understand the scientific facts—not become a peddler of cheap propaganda—but help pupils to see how science may, and must relate to the solution of our civilization's most serious problems.

The pupils of our cities want lots of things that they know not even of. Luther Burbank puts it nicely when he says: "Every child should have mud-pies, grasshoppers, water-bugs, tadpoles, frogs, mud-turtles, elderberries, wild strawberries, acorns, chestnuts, trees to climb, brooks to wade in, water-lilies, woodchucks, bats, bees, butterflies, various animals to pet, hay-fields, pine-cones, rocks to roll, sand, snakes, huckleberries and hornets; and any child who has been deprived of these has been deprived of the best part of his education." But our machine-made civilization, with its tangle of tenement flats, stale air, nerve-wracking jobs and noises, cement and cinders for play grounds, so-called "living wage" schedules, cheap stale foods, the haunting fear that ever dogs the steps of adults and youth alike—this is the scientific problem of our day. And he who in a science class dares to teach less than scientific truth, leaves a heavy load for the children to carry; and if there is any law of right written in the book of life, it has been broken.

George Bernard Shaw has said: "Liberty is the breath of life to nations: and liberty is the one great thing that parents, school masters and rulers spend their lives in extirpating for the sake of an immediately quiet and finally disastrous life."

COLLEGIATE COURSES IN MATHEMATICS FOR PROSPECTIVE HIGH SCHOOL TEACHERS.

By M. O. Tripp,

Wittenberg College, Springfield, Ohio.

Professor Hanus of Harvard, writing about twenty-five years ago, suggested an ideal preparation for high school teachers of mathematics. I wish to discuss this outline with a view to suggesting some changes which the last quarter of a century naturally impels us to make. His outline is as follows:[1]

"Advanced algebra, about fifty lessons; theory of equations (together with determinants and complex numbers), about fifty lessons; solid geometry, about fifty lessons; trigonometry, plane and spherical, about fifty lessons; surveying, about fifty lessons; calculus, about one hundred lessons; descriptive geometry, about fifty lessons; mechanics, about one hundred lessons; history of mathematics, about fifty lessons; physics (general, with quantitative laboratory work), about one hundred lessons; astronomy, about fifty lessons; chemistry, including mineralogy, about one hundred lessons; application of the calculus to light and heat, or to electricity, about one hundred lessons; history and theory of education, about one hundred lessons; methods, about fifty lessons."

When we consider the actual qualifications of high school and college teachers for the last five years it would seem that this outline, in general, applies to college instructors rather than to high school teachers; for there have been many college teachers of mathematics who have actually fallen below the standard set by the Harvard Professor. The great scarcity of strong teachers at the present time makes it really impossible to carry out this scheme of preparation, except in a very few large cities where fine salaries are paid. Many of the strong students in mathematics enter the engineering profession. It seems to be necessary, therefore, since we cannot get what we want, to take what we can get, and set up requirements that are not so advanced that prospective high school teachers will not undertake to carry them out. We must remember that a large percentage of the high school teachers of mathematics at the present time have had almost no collegiate preparation in mathematics; and it is a pity that they were not induced while in college to take something in the line of a connected course in mathematics that would prepare them for teaching that subject.

[1]*Educational Aims and Values*, p. 153.

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In any outline of courses for prospective teachers it would be well to keep in mind the mathematical preparation of the average student when he enters college. So much time has to be spent in the first year of collegiate mathematics in re-laying foundations and in teaching what was supposed to have been learned in the high school that the "College Algebra" at the present time, as taught in the average American college, can be very little more than a review of elementary algebra. After taking his first course in collegiate algebra, the student should be given a second course (preferably in the sophomore year) which may properly be called advanced algebra. In this course advanced topics in algebra, such as the elementary theory of equations, permutations and combinations, complex numbers, and determinants can be taken up. The freshmen courses in algebra are generally so clogged with students who want credits, but who are unable or unwilling to do real thorough work in algebra, that advanced topics cannot be studied. These two courses, together with the algebra that the student gets in the ordinary course in analytic geometry, furnish a fair preparation for teaching, so far as the subject matter of algebra is concerned.

In the matter of preparing prospective teachers for giving instruction in plane geometry in the high school the colleges have not given very much direct help. It is true that college professors frequently offer courses in projective geometry, which is a help; but this kind of geometry is not directly applicable, to any marked degree, to the work of the high school. The colleges should, I believe, offer a course in geometry that is an easy extension of the ordinary plane geometry, and at the same time gives considerable review of the high school work. I have given, on two occasions, with a fair degree of success, a course in the modern developments of geometry, three hours per week

for one semester, based upon *Godfrey and Siddon's Modern Geometry* (Cambridge University Press) with much stress upon the solution of exercises. In fact there is a small amount of theory in the book. Any student who will solve one-third of the seven hundred exercises in the text, the choice being made to cover every topic, will get a fine review of elementary plane geometry and an excellent foundation for taking up certain topics in higher mathematics. The topics covered are as follows: Sense of a line, infinity, centroid, various circles and straight lines connected with the plane triangle, theorems of Ceva and Menelaus, harmonic section, pole and polar, orthogonal circles, coaxal circles, inversion, orthogonal projection, cross-ratio, and the principle of duality. A course with this text as a basis should not be undertaken with freshmen unless the students are carefully selected, for the average high school student entering college does not possess sufficient penetrating power to get along smoothly in the work. It is well to mention that this course forms an excellent introduction to the usual course in projective geometry.

It seems to me inadvisable to offer a separate course in the history of mathematics for prospective high school teachers. The range of knowledge of nearly all undergraduate students of mathematics is so limited that it is practically impossible to vitalize all the statements made in the average history of the subject—especially is this true in the field of modern mathematics. It is, of course, highly desirable that the high school teacher should know something about the history of elementary mathematics; but this can best be done in connection with a teachers' course covering methods, or in connection with the study of subject matter. The plan of special reports by students on historical topics well within the range of the students' knowledge is a commendable one.

With regard to the preparation of students in space geometry it would seem that colleges should contribute more in the way of instruction than they are now doing. Ordinary solid geometry is not getting the attention it should have. Many colleges do not offer it, feeling that it should be given in the high school. A large percentage of students entering college have not had solid geometry, and since they have been allowed to enter without conditions, it is naturally incumbent upon the colleges to provide instruction in the subject; and this should be given with such a degree of thoroughness that the whole subject is taken

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up as demonstrative geometry, including the work on the sphere. It is unfortunate that many high schools and some colleges take up solid geometry largely from the standpoint of computation. For the teacher of ordinary arithmetic in the upper grades a training in solid geometry should prove very helpful when it comes to instruction in mensuration.

At the present time there are comparatively few students who enter college with a knowledge of spherical trigonometry, and hence the college must provide the instruction. The best scheme so far as training teachers is concerned is to correlate the spherical trigonometry with work in geography and astronomy by means of simple exercises. When this is done there

seems to be little need of a separate course in astronomy. Moreover, by this kind of a course the geometry of the sphere may be made more vital to the student.

Descriptive geometry, as a subject of study in liberal arts colleges, has not been greatly emphasized. Usually it is looked upon as a kind of drawing to be taken up only by engineers. But the prospective high school teacher will find this subject of great advantage in the development of space intuition. Many of the problems of solid geometry can be thoroughly vitalized by work in descriptive geometry. The graphical solution of all problems of spherical trigonometry by methods of descriptive geometry shows the great power of the subject in analyzing space.

Work in plane surveying is very helpful for the future teacher of mathematics. Going into the field with transit and measuring tape to make up problems furnishes the student with a concrete foundation in geometry and trigonometry which it is hard to gain otherwise. The various methods of checking surveying problems make the important matter of verification in mathematics very real to the student. The work in surveying may be closely correlated with drawing to scale. It cannot help but arouse interest for the student to learn that all the mensuration problems of plane trigonometry can be solved graphically on the drawing board, thus affording an excellent check for computational work with tables.

With regard to work in the calculus as a preparation for the high school teacher I wish to make a radical departure from the outline suggested by Professor Hanus. Preparation along elementary lines should naturally precede an attempt to cover advanced work. Calculus does not connect closely with high school mathematics; and consequently a teacher may be able to render very efficient service in secondary mathematics without a knowledge of that usual sophomore subject. It is true that a good student working carefully through the calculus will obtain a facility in algebra that will be helpful, but that same facility may be obtained in other ways. At times college professors of mathematics seem to be going too far in encouraging poor students to undertake such a subject as the calculus. Students who barely squeeze through an elementary course in analytic geometry should be advised to drop mathematics at that point. Calculus must naturally be kept in the college curriculum for those students who are enthusiastic about mathematics and who take pleasure in serious study.

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When it comes to giving a teachers' course in mathematics it is not easy to say just what should be attempted. The mere following of a text makes the work somewhat dull and uninspiring. On the other hand the giving of lectures seems to be unnecessary in view of the excellent texts that are now in existence. However, there is a field of mathematics not covered by the usual college courses which may suitably be made the basis of a course for teachers, and the regular treatises on the teaching of mathematics used as supplementary. The fundamental principles of high school mathematics should be treated with great thoroughness. I have found it helpful to get the students to take *Fine's College Algebra* as a regular text, for a time, and cover the theory of the subject so far as the usual topics of elementary algebra are concerned. For example, the study of simultaneous simple equations, as treated by Fine, will give the student quite a new point of view if he works it all through carefully. There are numerous topics, along the line of fundamental principles, that may be taken up through special reports by students and discussions by the class. A critical examination of current texts is important. Typical problems should also be solved together with various forms of checking. The one great danger in teachers' courses is that of making the work too simple and easy. Students should continually be held accountable for a thorough mastery of subject matter. The broadening of the student's horizon in reference to mathematical literature in the secondary field should receive considerable attention.

The outline stated in this article is meant to be in the form of notes or hints which may prove helpful to those who are giving or contemplating the giving of courses in mathematics for teachers. It is also hoped that it may be of guidance to teachers in secondary schools who wish to extend their knowledge along the line of high school mathematics. This attempt to sketch helpful courses for teachers is meant as a minimum rather than as a maximum requirement. Naturally the more mathematics the college student can take the better prepared he will be for teaching that subject.

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HIGHEST POINT IN FLORIDA IS 325 FEET ABOVE SEA LEVEL.

What does the average citizen know about our most southern State? Oh, Florida is rather warm, perhaps a little warmer than California; Florida produces excellent oranges and grapefruit; Florida is generally low and has an immense swamp in its southern part. Isn't that about all that many of us can say? The United States Geological Survey, Department of the Interior, which is making a topographic atlas of the entire United States, is able to furnish a very satisfactory physical picture of Florida, although it has mapped in detail only, a part of this interesting State.

It is true that Florida is low, the highest determined point in it—Iron Mountain, in Polk County—being only 325 feet above sea level, yet its surface shows considerable diversity. The southern part of the peninsula, known as the Everglades, comprising an area about 150 miles long and over 100 miles in average width, lies in general less than 50 feet above sea level. Much of this area is an almost impassable morass, and was once supposed to be below sea level. Lake Okechobee, a shallow body of fresh water at the north end of the Everglades, covers 730 square miles, and its surface is less than 20 feet above sea level. Narrow strips of lowland inclose the Everglades along the Atlantic and Gulf Coasts.

Down the middle of the peninsula north of the Everglades is a ridge in which more or less rounded depressions are separated by narrow divides. At some places this highland reaches an elevation of more than 300 feet. In the northern part of the State is another upland which rises at its highest part 300 feet above sea level. This upland, which is near the northern boundaries of Gadsden, Walton, Santa Rosa, and Escambia counties, is deeply dissected by rather steep-sided valleys.

Tallahassee, the capital of Florida, stands in regal seclusion on the edge of a remnant of the upland which has been isolated by erosion. From the highest part of the town, which is over 200 feet above sea level, the surface slopes down to a level of 80 feet or less.

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SOLUTION OF PROBLEMS

776. *Proposed by J. F. Howard, Brackenridge High School, San Antonio, Tex.*

Through the point P in the base BC of a $\triangle ABC$ draw a line XY such that $\triangle AXY : \triangle ABC = m : n$, where X is a point on AB produced and Y is a point on AC.

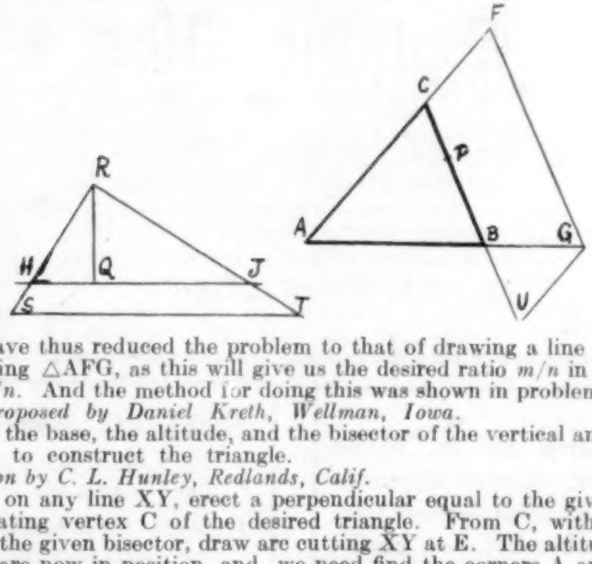
Solution by F. A. Cadwell, St. Paul, Minn.

Draw a line $HJ = n + 2m$, dividing HJ into two parts, $HQ = n$ and $QJ = 2m$. Let QR be the mean proportional between HQ and QJ. On RH take $RS = BC$, and through S draw a line parallel to HJ and meeting RJ in T. On CB take $CU = RT$ and draw UG $\parallel$ to AC meeting AB in G. Draw GF $\parallel$ CU meeting AC in F.

Then $RJ^2 = JQ \times HJ$ and $RH^2 = HQ \times HJ$. Hence $RJ^2/RH^2 = JQ/HQ = 2\ m/n$. Also $RJ/RH = RT/RS$ so that $RJ^2/RH^2 = RT^2/RS^2 = 2\ m/n$.

From the parallelogram FCUG, $FG = CU = RT$. Also $RS = BC$. Hence $RT^2/RS^2 = GF^2/BC^2 = 2\ m/n$.

Then $\triangle AFG/\triangle ABC = FG^2/BC^2 = 2\ m/n$.



We have thus reduced the problem to that of drawing a line through P bisecting $\triangle AFG$, as this will give us the desired ratio m/n in place of the $2\ m/n$. And the method for doing this was shown in problem 754.

777. *Proposed by Daniel Kreth, Wellman, Iowa.*

Given the base, the altitude, and the bisector of the vertical angle of a triangle, to construct the triangle.

Solution by C. L. Hunley, Redlands, Calif.

At D, on any line XY, erect a perpendicular equal to the given altitude locating vertex C of the desired triangle. From C, with radius equal to the given bisector, draw arc cutting XY at E. The altitude and bisector are now in position, and we need find the corners A and B.

Draw $\angle ECF = \angle ECD$; draw $CG \perp CF$. On CF take $CH = 1/2$ given base, and draw HG. On HG take $HJ = HC$.

From G draw an arc with radius $= GJ$, cutting XY at B (which will be one of the desired vertices). Instead of measuring the base

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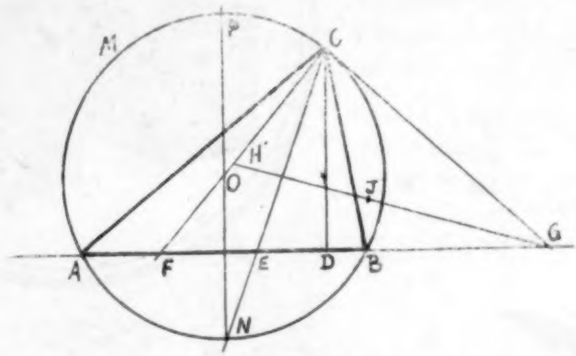
from B, our proof will be easier if we now draw the $\perp$ bisector of BC cutting FC at O, then use O as center and OB as radius to draw a circle cutting XY at A (which is the third vertex of the desired triangle.)

Proof: Extend CE to intersect circle at N. Make arc AM = arc BC. Draw NP to midpoint of arc MC. Then $\angle$CGB = $\angle$FCD (both complements of $\angle$CFE), and $\angle$CGB = 2$\angle$ECD. Also $\angle$CGB = 1/2 (arc AC—arc BC) = 1/2 arc MC.

$\angle$CNP = 1/2 arc PC = 1/4 arc MC. Hence $\angle$CNP = 1/2$\angle$CGB = $\angle$ECD, so that NP $\parallel$ CB and NP$\perp$AB. Then NP must pass through center of circle O, and N is the midpoint of arc ANB, so that $\angle$ACE = $\angle$BCE. This proves that EC is the bisector of the vertex angle C.



We must still prove that AB equals the given base.

$CG^2 = HG^2 - CH^2 = (GJ+JH)^2 - JH^2 = GJ\ (GJ+2\ JH)$.

Also $CG^2 = GB(GB+BA)$, since CG is a tangent, or $CG^2 = GJ(GJ+BA)$. Hence $GJ(GJ+BA) = GJ(GJ+2JH)$. From the last equation it follows that BA = 2JH; and as JH, or CH, was chosen as half the given base, the line BA is the correct base.

An analytic method of solving the problem was given by *Nelson L. Roray, Metuchen, N. J.*, and by *Michael Goldberg, Philadelphia, Pa.*

778. *Proposed by Norman Anning, Ann Arbor, Michigan.*

A textbook on trigonometry has for $\sin(x+a) = b \sin x$ the solution

$$\tan(x+1/2a) = \frac{b+1}{b-1} \tan 1/2a.$$

Show that this solution is consistent with the simpler solution:

$$\cot x = (b - \cos a)/\sin a.$$

I. *Solution by Henry Ruzicki, St. Martin's College, Lacey, Wash.*

$$\frac{\tan x + \tan 1/2a}{1 - \tan x \tan 1/2a} = \frac{b+1}{b-1} \tan 1/2a.$$

Clearing of fractions and using the relation for tan 1/2a, this equation becomes

$$(2b - 2\cos a) \tan x = 2 \sin a, \text{ or}$$
$$\cot x = (b - \cos a)/\sin a.$$

II. *Solution by Nelson L. Roray, Metuchen, N. J.*

$$x + 1/2a = n\pi + \tan^{-1} \frac{(b+1)}{(b-1)} \tan 1/2a.$$

$$x = n\pi + \tan^{-1} \frac{(b+1)}{(b-1)} \tan 1/2a - 1/2a.$$

$$\tan x = \frac{\frac{b+1}{b-1} \tan 1/2a - \tan 1/2a}{1 + \frac{b+1}{b-1} \tan^2 1/2a} = \frac{\sin a}{b - \cos a}$$

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$\cot x = (b - \cos a)/\sin a$.

III. *Solution by Michael Goldberg, Philadelphia, Pa.*

Without proving the consistency of the two solutions, the following derives the second solution geometrically.

Consider $\triangle DEF$, with $EG \perp DF$. Let $\angle D = x$, $\angle F = a$, $EF = 1$, $DF = b$. By the law of sines for $\triangle DEF$, $\sin(x+a) = b \sin x$, which is the equation to be solved. But $DG = b - GF = b - \cos a$, and $EG = \sin a$. Hence

$\cot \angle D = \cot x = DG/EG = (b - \cos a)/\sin a$.

Also solved by *T. E. N. Eaton, Redlands, Calif.; Fred A. Lewis, University, Ala.; L. R. Kellam, Culver Military Academy, Ind.; Harlow Lazott, Worcester, Mass.; and R. T. McGregor, Elk Grove, Calif*

779. The editor is frequently asked for solutions of the following:

Solve (1) $x^2+y = 7$; (2) $y^2+x = 11$.

Show how the biquadratic equation, which this leads to, is reduced to a cubic and solve the cubic by means of the trigonometric relation $4\sin^3\theta - 3\sin\theta + \sin 3\theta = 0$.

I. *Solution by N. L. Roray, Metuchen, N. J.*

The following solution is from *Fisher and Schwatt's Algebra*, p. 576.

Multiply (2) by x and subtract (1) : $xy^2 - y = 11x - 7$. To this equation add (2) multiplied by 2 getting

$$xy^2 - y + 2x + 2y^2 = 11x + 15.$$

Solving for y: $y = [1 \pm (6x+11)]/2(x+2)$.

The + sign gives $y = 3$ (and then $x = 2$)

The — sign gives $y = -(3x+5)/2(x+2)$ and this leads to the cubic equation $x^3+2x^2-10x = 19$.

II. *Solution by J. K. Elwood, Philipsburg, Montana.*

A combination of (1) and (2) gives $11 - x = (7-x)^2$. To each member of this equation add $2x^3+4x^2-20x$, and the result is factorable into $x(x^3+2x^2-10x-19) = 2(x^3+2x^2-10x-19)$ which gives one solution $x = 2$ and then leaves a cubic to be solved.

The solution $x = 2$, $y = 3$ may also be found by using the substitution $x+y = m$.

III. *Solution by H. Lazott, Worcester, Mass.*

Since $y = 7 - x^2$ we find the biquadratic $x^4 - 14x^2 + x + 38 = 0$ by direct substitution. By trial we find $x = 2$ is one solution, and we reduce the equation to $x^3+2x^2-10x+19 = 0$. Putting $u = 3x+2$, this reduces to $u^3 - 102u - 317 = 0$. Now substitute $r \sin\theta = u$ and multiply the equation by $4/r^3$, getting

$$4\sin^3\theta - (3 \cdot 136 \sin\theta)/r^2 - 1268/r^3 = 0$$

But $4\sin^3\theta - 3\sin\theta + \sin 3\theta = 0$; and hence

$$r^2 = 136, \text{ and } \sin 3\theta = -1268/r^3.$$

Then $\sin 3\theta = -.7995$, and $\theta = 17°41'38''$. Since 3θ can be increased by multiples of 360° without changing the sine, θ can be increased by multiples of 120°, and we have in fact 3 different values of θ. These 3 values when used in $u = r\sin\theta$, give $u = -3.5444, -7.8495, 11.3939$ and the corresponding values of x are $-1.8481, -3.2832, 3.7980$. (a fourth value $x = 2$ was mentioned earlier). The corresponding values of y can then be found and we have a complete solution of the two equations.

780. *For high school students.*

In an advertisement in a daily paper are shown three rectangles whose dimensions are: first, 2.6 by 1.6; second, 3.6 by 2,6; third, 4.6 by 3.8. Are these dimensions correct if the rectangles are to represent \$2,191, \$4,801, and \$10,519 respectively?

Solution by Ellsworth Billig, Redlands H. S., California.

The area of the first rectangle is 4.16 and if it represents \$2,191 then each square inch, foot, or unit represents \$526.68. Then to correspond with the first rectangle, the second and third rectangles should also represent \$526.68 per unit. But the area of the second rectangle is 9.36 and so represents \$4,929.72, and the area of the third rectangle is 17.48 and so represents \$9,206.36. These figures are not the ones quoted for

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the second and third rectangles; hence the dimensions of these rectangles is wrong.

Also solved by the following from the *Redlands High School: Adelaide Jenkins, Richards Robbeth, Kenneth Smith, and Frances U. Buckmaster.*

The editor considers this solution very satisfactorily but was not expecting the problem to be solved by this method. Is this not a problem in geometry on similar polygons? The sums $4,801 and $2,191, for example, should be proportional to the area of the two rectangles; and the square roots of these numbers then represents the ratio of any two corresponding sides of the similar polygons. In other words, we have here a practical use for the theorem: The ratio of the sides of two similar polygons is the square root of the ratio of the areas. The problem is a very excellent one for use in class as the pupils are anxious to see if the advertiser is honest in his representation of how fast money grows. Teachers may find similar problems frequently in the *Literary Digest*, and the editor suggests they keep a few on file always as the pupils find them very interesting.

PROBLEMS FOR SOLUTION

791. *Proposed by Elmer Schuyler, Bay Ridge High School, Brooklyn, N. Y.*

Given x, y, a, b as integers in the equations

$$(1)x^2+y = a,\ (2)x+y^2 = b,$$

what relation must exist between a and b so that a solution is possible? Show that there can not be two solutions for a given pair of values for a and b.

792. *Proposed by Paul Ligda, Oakland, California.*

Mail arrives at a uniform rate during the day. To dispose of this mail and of the mail accumulated before business hours the practice was to put the entire force of 22 clerks to work at the beginning of the working day, the job being finished in 20 minutes. The number of clerks was reduced to 12. These would catch up with the work in one hour. As it is desired to reduce the office force still further, the manager wishes to know: 1—How many clerks would be needed to catch up with the incoming mail in 5 hours. 2—How many clerks would be needed to keep up with the incoming mail the rest of the day.

793. *Proposed by J. K. Elwood, Philipsburg, Montana.*

From a point C two tangents CA and CB are drawn to a circle. CA = CB = 1/4 mile. The major arc AB = 1/2 mile. Find the size of $\angle$ACB.

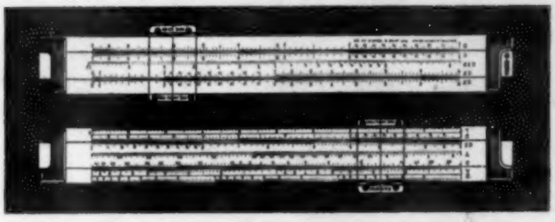
794. *Proposed by J. F. Howard, Brackenridge High School, San Antonio, Texas.*

Given three points A, C, B in a plane. Find the locus of P if $PA^2+PB^2+PC^2$ is constant.

795. *For high school pupils. Proposed by J. K. Ellwood, Philipsburg, Mont.*

What price can a buyer afford to pay for a $100 4 1/2 per cent bond having 10 years to run, interest payable semi-annually, in order that he may realize 6 per cent per annum, payable semi-annually?

The Slide Rule in Trigonometry



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Please send copies of examination questions of all kinds. [Test questions are particularly desired. (Compare Nos. 403, 405, 406. These questions are *test* questions.)]

What are your answers to problems 403, 405, 406?

Examination Paper

From the September, 1922, examination of Massachusetts Institute of Technology.

PHYSICS.

Time: two hours.

Answer any eight questions.

1. Between two hooks on the same level and 24 feet apart, a 26 foot rope hangs. The rope supports a weight of 100 pounds at the middle. By means of a diagram determine the pull on each hook.

2. It takes about four times as great a thrust to drive an airplane 80 miles an hour as it does at 40 miles an hour. Compare the horsepowers at the two speeds. Define power.

3. Explain exactly what is meant by the statement that an 8 pound body has a speed of 30 feet per second and at the same time an acceleration of 5 feet per second per second. How far away will this body be after 2 seconds? What was its average speed during those two seconds? What force is necessary to make it behave like this?

4. A hole 1 foot by 6 inches is cut in the flat bottom of a boat drawing 18 feet of water. What force must be exerted to hold a board tightly against the inside of the hole?

5. A man and a child are sitting on a see-saw. The plank weighs 50 pounds and will just balance alone. If the child weighs 60 lbs. and is 10 feet from the pivot, where must the 150 pound man be to balance? What total weight must the pivot support?

6. Explain the difference between sound waves and light waves. Explain beats and overtones. What is the distinction between the pitch of a sound and its loudness?

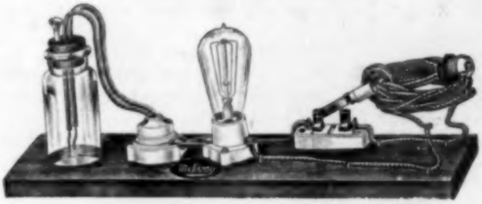
7. An electrically welded car rail 1 mile long has a coefficient of expansion of 0.0000058 per degree Fahrenheit. How much longer will it be when its temperature is 80° F. than when its temperature is—10°F.? If it is so surrounded on every side that it cannot move, what will it then do?

8. Is a 5 ampere fuse satisfactory for a 500 watt flat iron on a 110 volt circuit? Explain. What does it cost to run this flat iron 15 minutes at 10 cents a kilowatt-hour? What is the electrical resistance of the flat iron? If two of these flat irons were run in series in the same circuit, would they operate at the required high temperature? If not, why not?

9. Is there any connection between magnetism and electricity? Is it possible to produce a magnet with the aid of electricity? To produce a current of electricity with the aid of a magnet? Explain. Which will exert the greater attraction on a charged pith ball, a steel magnet or a piece of copper of the same dimensions as the magnet?

10. What kind of lens will be needed to form an image on a screen 36 feet from the lens and magnified 12 diameters? What must be the focal length of the lens? Draw a diagram showing position of object, lens, and image.

Electrical Conductivity
of Solutions



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PROBLEMS AND QUESTIONS FOR SOLUTION

412. *Proposed through the courtesy of the Cox Brass Mfg. Co., Albany, N. Y., and Cleveland, Ohio.*

A Hylo bumper stands the test indicated in the accompanying data.

The effective length of suspended cable is 34 ft.

The falling weight 650 lbs.

When the distance of travel is 20 feet as indicated, the velocity at the moment of impact on the bumper is 20.4 ft. per second, or 14 miles per hour, and the striking force of the weight in foot-pounds is 4225.

Check up these results and send in your methods of solution.

413. What force does the falling weight exert at the moment of inpact?

414. *Proposed by S. G. Rich, New York University, New York City.*

Why is it that although the osmotic pressures of various solutions are exceedingly great, it is not possible to get a large and extremely rapid rise of liquid when the ordinary inverted thistle-tube apparatus, either with the usual animal membrane or the silicate membrane described in this journal in December, 1922, is used? With pressures of the magnitude claimed, surely an inch an hour is a very small rise.

SOLUTIONS AND ANSWERS

402. *Proposed by E. M. Schultheis, Chief of Drafting Room, The White Motor Co.*

A road is one mile up hill and one mile down hill. An automobile driver travels up the hill at 15 miles per hour. How fast must he travel down hill to maintain an average speed of 30 miles per hour?

Solution by J. C. Packard, Brookline, Mass.

1. Solution is impossible, for, an average of 30 miles an hour would mean four minutes for the entire trip whereas by the conditions of the problem the car consumes four minutes in the first half of the trip leaving no time at all for the second half, or the journey down hill. The speed down hill therefore would have to be infinity.

2. Treated algebraically. Let $x =$ the miles per hour down hill. Then $1/x =$ time going down hill: $1/15 =$ time going up hill: total time $= 1/x + 1/15$: average speed $= \dfrac{2}{1/x+1/15}$ Whence equation becomes $\dfrac{2}{1/x+1/15} = 30$. $1 = 15/x + 1$. $15/x = 0$. $Ox = 15$, $x + 15/0$, $x =$ infinity.

Note by Editor: Try this problem with any class. The favorite answer is 45 miles per hour $\dfrac{15+45}{\surd} = 30$, *check*.

This problem will *test* the thinking capacity (or habit) of the individual solver. Many people, particularly those who *know* or *suspect* that they can not think, will refuse to answer.

403. Which is the better physicist—Mutt or Jeff?

(See cow problem in February, 1923, number of SCHOOL SCIENCE AND MATHEMATICS.)

Several answers have been received but they do not fully agree. See the following quotations:

No. 1. "Mut is the better physicist?"

No. 2. "Jeff is the better physicist as the cow can be weighed in this manner, except ...."

No. 3. "Perhaps the simplest solution would be to use two scales so that the cow would have its front feet on one and its hind feet on the other."

What is your answer to the Mutt and Jeff cow problem?

404. *Proposed by H. Hugh Jones, Carmi, Ill.*

I have been comparing some physics texts and I notice that Carhart & Chute's *Practical Physics* says the momentum equation is

ft $= mv$ (Force$\times$time equals mass$\times$velocity). The new edition of Black and Davis does not mention the momentum equation but the

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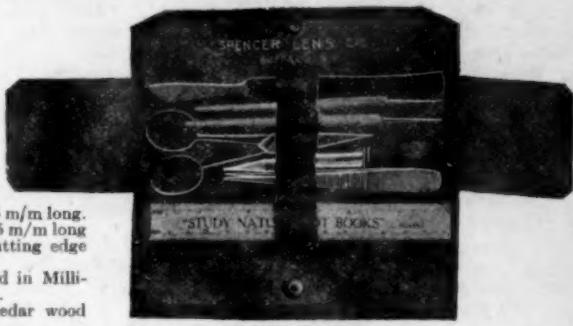

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old edition of Black & Davis' *Practical Physics* gives the equation as $ft = wv/g$ (force × time equals weight × velocity divided by gravity.)

Since *mass* and *weight* are numerically equal, the equations are the same except for the use of gravity in the second.

What is the effect of the use of g in the equation?

Here is a problem to illustrate:

A body of 50 grams is moving with a velocity of 20 centimeters per second. What is the momentum of the body?

According to the first equation, the momentum (ft) is $m\,v$, or 50×20 which is 1,000. By the second equation it is $w\,v/g$, or $50 \times 20 \div 980$.

Solutions were returned by

Miss Carmen Amill, Mayagüez H. S., Mayagüez, Porto Rico.
John M. Michener, Wichita H. S., Wichita, Kans.
Niel F. Beardsley, Georgia School of Tech., Atlanta, Ga.
Stephen G. Rich, New York City.

Solution by Miss Carmen Amill, Mayagüez, Porto Rico.

The effect of using g in the equation is that it makes "the slug" or the "gee-gram" the unit of mass; that is, 980 grams as the unit of mass.

$\frac{W}{g} = m$, when, W is in *dynes* or (poundals) then g in cm/sec² or (ft./sec²) and m in grams or (lbs.).

Therefore problem should be solved when using Black & Davis equation, reduce grams to dynes and substitute in equation $F\,t = \frac{Wv}{g}$

$$\frac{50 \times 980 \times 20}{980} = F\,t = 1{,}000.$$

Solution by Neil F. Beardsley, Atlanta, Ga.

Prob. 404 seems to be fundamentally a question of units. There is a great variety of definitions for units of some of our most common physical quantities and each definition is, I think, right in proportion to the number of people using it. Likewise there is a similar variety of forms for expressing many familiar relationships each of which may also be tested by its popularity. But one must consult nature when deciding on the definitions to use in any particular formulation of a law, or when deciding on the form of a law to use with any particular set of definitions. In other words every physical law involves quantities which must be defined and then relationships between these quantities. Man may make either as he wishes but having decided on one, nature must be permitted to decide the other. As a result of this condition we have in different texts contradictory equations but then there must also be contradictory definitions. Thus each text starting from a different point may be in itself consistant. These conditions are particularly true in mechanics where there are so many different units, for the same quantity, frequently with the same spelling even.

Personally I have found the following scheme of units most suitable in the classroom:

The fundamental unit of mass should be the 1/1000 of the standard kilogram (gram)

The fundamental unit of length should be the 1/100 of the standard meter. (centimeter)

The fundamental unit of time should be the 1/86400 of the mean solar day. (second)

Then I express Newton's Second law as $F = MA$ (I am not teaching graduate students)

To get a unit of force, let $M = 1$gm. and $A = 1$ cm/sec² and F must equal 1 "something." The force which will give to a mass of one gram an acceleration of one cm per sec per sec is a dyne. A gram mass will fall with an acceleration of "g" due to the force of attraction between itself and the earth, i. e., its weight. Therefore a gram mass must weigh

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"980" dynes. Work being expressed by $W = FS\cos\theta$ (force times distance times cosine of angle between them). The unit of work must be the work done by one dyne in moving one cm in its own direction. This is the dyne-cm. or erg.

Example. K. E. = $1/2\ MV^2$. If the mass is in grams and the velocity in cm/sec the work must be in dyne-cm. or ergs.

Momentum = MV must give gm-cm/sec.

Momentum = $wV/g = (Mg)V/g : MV = FT$: dyne.sec = qm.cm/sec

Or the equations in the question are identical. I believe no special name has ever been given to a unit of momentum.

Due to the work done in mechanics by the engineers another set of units is necessary.

Unit of length as before (cm)

Unit of time as before (sec).

Unit of *force* should be the gram of force which is 1/1000 of the weight of the standard kilogram and of course depends on the value of "g" at any particular place. So this set of units is called "gravitational" in contradistinction to the "absolute units" given above which are absolutely independent of the value of "g". Again F = MA. To get the unit of M, let F = 1 gram of force and A equal 1 cm/sec^2 then M must be one "something" and this I call a **metric slug**. Then a metric slug is the mass to which a force of one gram will give an acceleration of 1 cm/sec^2. For a freely falling object weighing a gram w = M."980" and M = w/980 then a metric slug must be equivalent to "980" grams of mass.

Work = $FS\cos\theta$ as before equals gram.cm.

K. E. = $1/2MV^2$ if mass is in slugs and V in cm/sec this must also give gm.cm.

Momentum = MV : slug.cm/sec = FT = gm(force)sec = wV/g = MgV/g = slug.cm/sec = gm(force).cm/sec.sec^2/cm = gm(force)sec.

English units equivalent to each of the above are available.

Metric	English
dynes	poundals
gram mass	pound mass
gram force	pound force
metric slug	slug

Table of Units

Absolute	mass	time	force	work	momentum
Metric	gm	sec	dyne	erg or dyne cm	gm.cm/sec or dyne.sec
English	lb	sec	poundal	ft.Poundal	lb.ft/sec or poundal.sec
gravitational					
Metric	m.slug	sec	gram	gram.cm	m.slug.cm/sec or gram-.sec
English	slug	sec	pound	ft.pound	slug.ft/sec or pound.sec

In the question asked each formula is consistent with these units and so the authors evidently had some such scheme in mind. The statement that the mass and weight are numerically equal is not consistent with any one set of units and would require a different scheme of units and then also a different form for the equations. The correct answer is of course 1000gm.cm/sec or 1000 dyne.sec.

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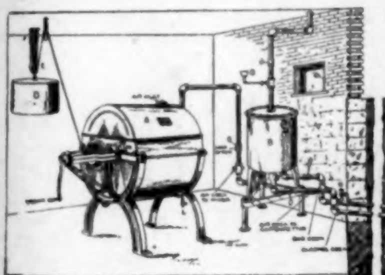

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The fifteenth session of the University of Michigan Biological Station will be held on the shores of Douglas Lake, Cheboygan County, Michigan, during the eight-week period from July 2 to August 24. This Station offers unique advantages for the study of a fauna and flora marked by the inclusion of the northern boreal forms and many of the forms characteristic of the region further south, the area being in the transition zone between the northern-eastern coniferous forest area and the central deciduous forest. The summer climate of this region is ideal for outdoor work of all kinds.

The Station is conducted as a camp, with log and frame buildings for laboratories and small frame houses and tents for living quarters. A mess, operated on the coöperative plan, furnishes table board for the members of the Station. Located six miles from the nearest village and three miles from the nearest farm house, the Station furnishes a fine experiment in community life. This isolation makes for a minimum of distraction and for concentration of interest upon biological work.

The class period lasts through the working day, thus permitting all-day field trips. Certain classes make two-or-three-day excursions to the sand dunes along the shore of Lake Michigan. The curriculum for this session has been enriched by the addition of new courses and the expansion of some of the old. Courses will be given in Ichthyology, Limnology, Entomology, Ornithology (two courses), Herpetology, and Mammalogy, Cryptogamic Botany, Taxonomy of the Bryophytes, Systematic Botany (two courses), Ecology and Plant Anatomy.

Classes are small; the teaching is done by experts; virtually no teaching is done by assistants. This brings about a degree of intimacy of contact between the instructor and the members of the class such as rarely exists in a university class. Students undertaking research under direction will find a wide variety of fields from which to select subjects for investigation. The more than one hundred and twenty-five published papers bearing on the biota of the region attest the interest of the former members of the Station and the encouragement given research by those in charge.

The teaching Staff will include Professor P. S. Welch and Dr. F. N. Blanchard of the University of Michigan; Professor H. B. Hungerford of the University of Kansas, and Mr. Francis Harper of Cornell University in Zoology; Professor J. H. Ehlers of the University of Michigan, Professor F. C. Gates of the Kansas State Agricultural College, Professor G. E. Nichols of Yale University, and Dr. H. A. Gleason of the New York Botanical Gardens in Botany. Mrs. Margaret T. Gates will serve as Dean of Women, and Dr. Warren E. Forsythe of the University of Michigan Health Service will be the physician.

Graduate students, when regularly matriculated in the University and properly registered with the Dean of the Graduate School, may carry on work at the Station which will count toward an advanced degree. The Master's degree may usually be secured by properly qualified graduates of other institutions upon the completion of four summer sessions spent in residence at the University. Candidates who propose to pursue work in Zoology or Botany and who have had broad training may, after consultation or correspondence with the Dean of the Graduate School, be permitted to fulfill the entire residence requirement by study at the Biological Station. Others may expect to be required to spend one or more summers at Ann Arbor.

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described in the November, 1922, issue by Prof. G. E. Ripley in his article on Hook's Law. Correspondence invited.

BOOK REVIEWS.

A First Book in Chemistry, by Robert H. Bradbury, A. M., Ph. D., Head of the Department of Science, South Philadelphia High School. First edition pp. xii plus 687. 2.5x13.5x19.5 cm. Many photographic reproductions, diagrams, etc. Cloth, 1922. D. Appleton & Co.

The first thing that strikes one on picking up this new chemistry text is its voluminous character. Six hundred and eighty-seven pages make quite a book, and gives the teacher who has but meager library facilities plenty of material, not only for the subject matter of the course, but also for reference purposes. The book has indeed much of industrial and applied chemistry within its covers and many excellent illustrations help in the presentation of this kind of chemistry.

There is plenty of the fundamentals of chemistry given as a necessary preliminary to the applied work. The order of presentation is not novel but is more or less like that which has become somewhat usual in the teaching of high school chemistry.

The later chapters of the book present some elementary organic chemistry with some of the chemistry of foods, and there is a chapter on war-gases and explosives. The final chapter deals with radio activity and sub-atomic structure. The book is thus quite up to date and is worthy of careful consideration by all high school teachers who are contemplating a change of text. F. B. W.

Analytic Geometry, Brief Course, by Lewis Parker Siceloff, George Wentworth, and David Eugene Smith. Pages vi+186, 15x21 cm. 1922. Ginn and Company, Boston.

This excellent textbook contains a good choice of topics for a course extending through one-half a year, and presents the subject in a clear and practical way. It treats of the essential features of the analytic method and gives a brief treatment of the theory in the space of three dimensions. The exercises are carefully graded as to difficulty and include some simple, practical applications. H. E. C.

Rapid Arithmetic, by T. O'Conor Sloane, Ph. D., LL. D. Pages viii+190. 13x19 cm. Price, $1.50. 1922. D. Van Nostrand, New York.

In the usual textbook in arithmetic for the most part only one method of performing an operation is given, but this book shows a dozen or more ways of adding, and several ways of performing the other fundamental operations. This not only adds to the pupil's interest but furnishes convenient checks on the accuracy of results. While this work is a supplement to the ordinary textbook in arithmetic, it will be found to be of practical application in real work because of the many short cuts in calculating. There are included many curious properties of numbers and arithmetical recreations. This book gives a teacher an opportunity for increasing his own interest and that of his pupils in mathematics.

H. E. C.

Geometry Notebook. Pages 50. 21x27 cm. *Graph Notebook.* Pages 50. 15x23 cm. Globe Book Company, New York.

Each sheet of the geometry notebook is ruled and spaced for theorem, hypothesis, to prove, proof, statements, reasons, notes, and diagram. The use of this form of notebook by pupils leads to clear thinking and orderly arrangement of work, and lessens the difficult task of the teacher. On the covers are printed directions for the pupil and important formulas. Each sheet of the graph notebook contains a large diagram ruled in squares and space for the problem to be written and for notes. On the covers are directions for constructing the graph of an equation and the squares of numbers to 100. H. E. C.